THE COLLECTED PAPERS

OF

JOSEPH, BARON LISTER

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Joseph Lister

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JOSEPH, BARON LISTER

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ETC., ETC.

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PART III

THE ANTISEPTIC SYSTEM

ON A NEW METHOD OF TREATING COMPOUND FRACTURE, ABSCESS, ETC.

WITH OBSERVATIONS ON THE CONDITIONS OF SUPPURATION

[*Lancet*, 1867, vol. i, pp. 326, 357, 387, 507; vol. ii, p. 95.]

ON COMPOUND FRACTURE

THE frequency of disastrous consequences in compound fracture, contrasted with the complete immunity from danger to life or limb in simple fracture, is one of the most striking as well as melancholy facts in surgical practice.

If we inquire how it is that an external wound communicating with the seat of fracture leads to such grave results, we cannot but conclude that it is by inducing, through access of the atmosphere, decomposition of the blood which is effused in greater or less amount around the fragments and among the interstices of the tissues, and, losing by putrefaction its natural bland character, and assuming the properties of an acrid irritant, occasions both local and general disturbance.

We know that blood kept exposed to the air at the temperature of the body, in a vessel of glass or other material chemically inert, soon decomposes; and there is no reason to suppose that the living tissues surrounding a mass of extravasated blood could preserve it from being affected in a similar manner by the atmosphere. On the contrary, it may be ascertained as a matter of observation that, in a compound fracture, twenty-four hours after the accident the coloured serum which oozes from the wound is already distinctly tainted with the odour of decomposition, and during the next two or three days, before suppuration has set in, the smell of the effused fluids becomes more and more offensive.

This state of things is enough to account for all the bad consequences of the injury.

The pernicious influence of decomposing animal matter upon the tissues

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has probably been underrated, in consequence of the healthy state in which granulating sores remain in spite of a very offensive condition of their discharges. To argue from this, however, that fetid material would be innocuous in a recent wound would be to make a great mistake. The granulations being composed of an imperfect form of tissue, insensible and indisposed to absorption, but with remarkably active cell-development, and perpetually renovated as fast as it is destroyed at the surface, form a most admirable protective layer, or living plaster. But before a raw surface has granulated, an acrid discharge acts with unrestrained effect upon it, exciting the sensory nerves, and causing through them both local inflammation and general fever, and also producing by its caustic action a greater or less extent of sloughs, which must be thrown off by a corresponding suppuration, while there is at the same time a risk of absorption of the poisonous fluids into the circulation.

This view of the cause of the mischief in compound fracture is strikingly corroborated by cases in which the external wound is very small. Here, if the coagulum at the orifice is allowed to dry and form a crust, as was advised by John Hunter,[1] all bad consequences are probably averted, and, the air being excluded, the blood beneath becomes organized and absorbed, exactly as in a simple fracture. But if any accidental circumstance interferes with the satisfactory formation of the scab, the smallness of the wound, instead of being an advantage, is apt to prove injurious, because, while decomposition is permitted, the due escape of foul discharges is prevented. Indeed, so impressed are some surgeons with the evil which may result from this latter cause, that, deviating from the excellent Hunterian practice, they enlarge the orifice with the knife in the first instance and apply fomentations, in order to mitigate the suppuration which they render inevitable.

Turning now to the question how the atmosphere produces decomposition of organic substances, we find that a flood of light has been thrown upon this most important subject by the philosophic researches of M. Pasteur, who has demonstrated by thoroughly convincing evidence that it is not to its oxygen or to any of its gaseous constituents that the air owes this property, but to minute particles suspended in it, which are the germs of various low forms of life, long since revealed by the microscope, and regarded as merely accidental concomitants of putrescence, but now shown by Pasteur to be its essential cause, resolving the complex organic compounds into substances of simpler chemical constitution, just as the yeast plant converts sugar into alcohol and carbonic acid.

A beautiful illustration of this doctrine seems to me to be presented in sur-

[1] See Works of J. Hunter, edited by Palmer, vol. i, p. 429.

gery by pneumothorax with emphysema, resulting from puncture of the lung by a fractured rib. Here, though atmospheric air is perpetually introduced into the pleura in great abundance, no inflammatory disturbance supervenes; whereas an external wound penetrating the chest, if it remains open, infallibly causes dangerous suppurative pleurisy. In the latter case the blood and serum poured out into the pleural cavity, as an immediate consequence of the injury, are decomposed by the germs that enter with the air, and then operate as a powerful irritant upon the serous membrane. But in case of puncture of the lung without external wound, the atmospheric gases are filtered of the causes of decomposition before they enter the pleura, by passing through the bronchial tubes, which, by their small size, their tortuous course, their mucous secretion, and ciliated epithelial lining, seem to be specially designed to arrest all solid particles in the air inhaled. Consequently the effused fluids retain their original characters unimpaired, and are speedily absorbed by the unirritated pleura.

Applying these principles to the treatment of compound fracture, bearing in mind that it is from the vitality of the atmospheric particles that all the mischief arises, it appears that all that is requisite is to dress the wound with some material capable of killing these septic germs, provided that any substance can be found reliable for this purpose, yet not too potent as a caustic.

In the course of the year 1864 I was much struck with an account of the remarkable effects produced by carbolic acid upon the sewage of the town of Carlisle, the admixture of a very small proportion not only preventing all odour from the lands irrigated with the refuse material, but, as it was stated, destroying the entozoa which usually infest cattle fed upon such pastures.

My attention having for several years been much directed to the subject of suppuration, more especially in its relation to decomposition, I saw that such a powerful antiseptic was peculiarly adapted for experiments with a view to elucidating that subject, and while I was engaged in the investigation the applicability of carbolic acid for the treatment of compound fracture naturally occurred to me.

My first attempt of this kind was made in the Glasgow Royal Infirmary in March 1865, in a case of compound fracture of the leg. It proved unsuccessful, in consequence, as I now believe, of improper management; but subsequent trials have more than realized my most sanguine anticipations.

Carbolic acid[1] proved in various ways well adapted for the purpose. It

[1] Carbolic acid is found in the shops in two forms—the glacial or crystalline, solid at ordinary temperatures of the atmosphere; and the fluid, which sometimes passes under the name of German creosote. The fluid variety is sold in various degrees of purity. The crude forms are objectionable from their offensive odour; but the properly rectified product is almost fragrant. Different samples, however, differ much in energy of action, and hence, though I have hitherto employed the liquid

exercises a local sedative influence upon the sensory nerves; and hence is not only almost painless in its immediate action on a raw surface, but speedily renders a wound previously painful entirely free from uneasiness. When employed in compound fracture its caustic properties are mitigated so as to be unobjectionable by admixture with the blood, with which it forms a tenacious mass that hardens into a dense crust, which long retains its antiseptic virtue, and has also other advantages, as will appear from the following cases, which I will relate in the order of their occurrence, premising that, as the treatment has been gradually improved, the earlier ones are not to be taken as patterns.

Case i.—James G——, aged eleven years, was admitted into the Glasgow Royal Infirmary on the 12th of August, 1865, with compound fracture of the left leg, caused by the wheel of an empty cart passing over the limb a little below its middle. The wound, which was about an inch and a half long, and three-quarters of an inch broad, was close to, but not exactly over, the line of fracture of the tibia. A probe, however, could be passed beneath the integument over the seat of fracture and for some inches beyond it. Very little blood had been extravasated into the tissues.

My house surgeon, Dr. Macfee, acting under my instructions, laid a piece of lint dipped in liquid carbolic acid upon the wound, and applied lateral pasteboard splints padded with cotton wool, the limb resting on its outer side, with the knee bent. It was left undisturbed for four days, when, the boy complaining of some uneasiness, I removed the inner splint and examined the wound. It showed no signs of suppuration, but the skin in its immediate vicinity had a slight blush of redness. I now dressed the sore with lint soaked with water having a small proportion of carbolic acid diffused through it; and this was continued for five days, during which the uneasiness and the redness of the skin disappeared, the sore meanwhile furnishing no pus, although some superficial sloughs caused by the acid were separating. But the epidermis being excoriated by this dressing, I substituted for it a solution of one part of carbolic acid in from ten to twenty parts of olive oil, which was used for four days, during which a small amount of imperfect pus was produced from the surface of the sore, but not a drop appeared from beneath the skin. It was now clear that there was no longer any danger of deep-seated suppuration, and simple water dressing was employed. Cicatrization proceeded just as in an ordinary granu-

kind in compound fracture, it would probably be better to use the crystallized form, melting it by placing the vessel containing it in warm water for a few minutes. Carbolic acid is almost absolutely insoluble in water, but dissolves readily in various organic liquids, such as the common fixed oils or glycerine.

lating sore. At the expiration of six weeks I examined the condition of the bones, and, finding them firmly united, discarded the splints ; and two days later the sore was entirely healed, so that the cure could not be said to have been at all retarded by the circumstance of the fracture being compound.

This, no doubt, was a favourable case, and might have done well under ordinary treatment. But the remarkable retardation of suppuration, and the immediate conversion of the compound fracture into a simple fracture with a superficial sore, were most encouraging facts.

Case 2.—Patrick F——, a healthy labourer, aged thirty-two, had his right tibia broken on the afternoon of the 11th of September, 1865, by a horse kicking him with its full force over the anterior edge of the bone about its middle. He was at once taken to the infirmary, where Mr. Miller, the house surgeon in charge, found a wound measuring about an inch by a quarter of an inch, from which blood was welling profusely.

He put up the fracture in pasteboard splints, leaving the wound exposed between their anterior edges, and dressing it with a piece of lint dipped in carbolic acid, large enough to overlap the sound skin about a quarter of an inch in every direction. In the evening he changed the lint for another piece, also dipped in carbolic acid, and covered this with oiled paper.[1] I saw the patient next day, and advised the daily application of a bit of lint soaked in carbolic acid over the oiled paper ; and this was done for the next five days. On the second day there was an oozing of red fluid from beneath the dressing, but by the third day this had ceased entirely. On the fourth day, when, under ordinary circumstances, suppuration would have made its appearance, the skin had a nearly natural aspect, and there was no increase of swelling, while the uneasiness he had previously felt was almost entirely absent. His pulse was 64, and his appetite improving. On the seventh day, though his general condition was all that could be wished, he complained again of some uneasiness, and the skin about the still adherent crust of blood, carbolic acid, and lint was found to be vesicated, apparently in consequence of the irritation of the carbolic acid. From the seventh day the crust was left untouched till the eleventh day, when I removed it, disclosing a concave surface destitute of granulations, and free from suppuration. Water dressing was now applied, and by the sixteenth day the entire sore, with the exception of one small spot where the bone was bare, presented a healthy granulating aspect, the formation of pus being limited to the surface of the granulations.

I now had occasion to leave Glasgow for some weeks, and did so feeling

[1] A cheap substitute for oiled silk, devised by the late Dr. M'Ghee, of the Glasgow Infirmary, and very useful for covering poultices, &c.

that the cure was assured. On my return, however, I was deeply mortified to learn that hospital gangrene attacked the sore soon after I went away, and made such havoc that amputation became necessary.

While I could not but feel that this case, by its unfortunate issue, might lose much of its value in the minds of others, yet to myself it was perfectly conclusive of the efficacy of carbolic acid for the object in view. At the same time it suggested some improvement in matters of detail. It showed that the acid may give rise to a serous exudation apt to irritate by its accumulation, and therefore that a warm and moist application would be advantageous to soothe the part, and also ensure the free exit of such exuded fluid. At the same time it appeared desirable to protect the crust with something that would retain the volatile organic acid more effectually than oiled silk or gutta-percha, through which it makes its way with the utmost facility. For this purpose a metallic covering naturally suggested itself, and as ordinary tin-foil is unsuitable from its porosity, I employed thin sheet-lead, and afterwards block-tin, such as is used for covering the jars of anatomical preparations, superior to lead on account of the facility with which it can be moulded to any shape that is desired.

For a long time, however, I had no opportunity of giving this improvement a trial, the compound fractures admitted into my wards during the next eight months being merely two cases with small wounds. One of these was a fracture of the ulna into the elbow-joint in a woman so old that suppuration, had it occurred, would probably have proved fatal. The orifice in the integument was extremely small, and all would most likely have gone on well had the bit of dry lint applied to check the free bleeding from the interior been left undisturbed, instead of being saturated with carbolic acid as it was. This, however, could not but be an additional safeguard, and at the same time it was satisfactory to find that the caustic application did not interfere with the usual healing by scabbing, cicatrization being found complete when the crust was removed.

The other case was a fracture of the humerus a little above the elbow in a young man, caused by a fall from a height of thirty-five feet, the wound, which was not quite half an inch in length, being situated at the inner side of the limb, where it must necessarily be covered by a splint. Dr. Watson, then my house surgeon, applied lint dipped in carbolic acid covered with a slightly concave piece of sheet-lead about as large as a shilling, and put up the limb in pasteboard padded with cotton. At the end of ten days the inner side of the limb was uncovered for the first time, and merely as a matter of curiosity, when the lead, with the lint adhering to it, dropped off, disclosing a small superficial granulating

sore without the slightest suppuration, just as in ordinary healing by scabbing. This case is interesting, not so much because the compound fracture was converted into a simple one, for this might have occurred under ordinary treatment, but because it showed that in any case of fracture complicated with a small wound, we have in carbolic acid a means which enables us to disregard the wound altogether after the splints have been applied, instead of being under the necessity of daily disturbing the apparatus to change the dressing.

At length a case presented itself well calculated to test the value of carbolic acid in compound fracture.

CASE 3.—John H——, aged twenty-one, a moulder in an iron foundry, was admitted on the 19th of May, 1866, with compound fracture of the left leg, produced in the following manner. He was superintending the raising by crane of an iron box containing sand ready for a casting, the box and its contents weighing about 12 cwt., when one of the chains by which it was suspended slipped, and the box fell from the height of four feet with unbroken force upon the inner side of his leg, which was planted obliquely beneath it. Both bones were fractured, the tibia about its middle, and a wound an inch and a half in length, and three-quarters of an inch broad, was made at the inner aspect of the limb, on a level with the fracture of the tibia, and obviously communicating with it. At the same time the soft parts generally were much contused, as was evident from the great distension of the limb with extravasated blood. Dr. A. Cameron, my house surgeon, finding, on manipulating the limb, that bubbles escaped along with the blood, implying that air had been introduced during the movements of the leg as the patient was being carried to the infirmary, thought it best that I should see the case, which I did at three p.m., three hours and a half after the accident. In order to expel the air I squeezed out as much as I could of the clotted and fluid blood which lay accumulated beneath the skin, and then applied a bit of lint dipped in carbolic acid slightly larger than the wound, and over this a piece of sheet-tin about four inches square. Finally the limb was placed in pasteboard splints, resting on its outer side with the knee bent. At eight p.m. some more acid was added with another piece of lint, so that the crust of clots, carbolic acid, and lint was about one-third of an inch in thickness. A hot fomentation also was applied over the inner aspect of the leg, the crust being protected by the tin. Next day he was pretty easy, and had passed a quiet night, though occasionally awakened by starting pains ; the pulse was 90, but he took some food with relish. The surface of the crust was touched again with carbolic acid, and the fomentation was continued, and in place of the internal pasteboard splint, a large sheet of tin was applied over the flannel

from the knee to the ankle, being retained in position by looped bandages. This proved a very satisfactory arrangement, the tin having sufficient firmness to answer the purpose of a splint, while it most effectually retained the moisture of the flannel, which, again, served as an excellent padding. The fomentation was changed night and morning, and gave great comfort to the patient, and once a day carbolic acid was applied lightly to the crust.

Two days after the accident the limb was easier, but the circumferential measurement of the calf continued the same, and the pulse was 96, though soft. On the fourth day—the critical period with reference to suppuration—the limb was free from pain, and the calf less tense, and distinctly reduced in dimensions; while the pulse had fallen to 80, and the patient had enjoyed his food after a good night's rest. After this the swelling steadily subsided, the skin remaining, as it had been from the first, free from the slightest inflammatory blush, and his general health was in all respects satisfactory. Seven days after the receipt of the injury there was some puriform discharge from the surface of the skin where the carbolic acid, confined by the smaller piece of tin that covered the crust, had produced excoriation by its caustic action; and to prevent needless irritation from this cause, the tin was reduced so as to leave only a narrow flat rim round a bulging part which corresponded to the crust.

About a fortnight after the accident a sense of fluctuation was experienced over the seat of fracture, but, as all was going on favourably otherwise, I hoped that this was due simply to serum from the effused blood; and in a few days it had completely disappeared, not a drop of pus meanwhile having escaped from beneath the crust. About this time the edges of the crust became softened by the superficial discharge from the surrounding parts, and these softened portions were daily clipped away with scissors. Thus the circumferential part of the crust which had overlapped the skin was removed, and that which lay over the extravasated blood in the wound was also reduced to smaller and smaller size.

On the 7th of June, nearly three weeks after the accident, an observation of much interest was made. I was detaching a portion of the adherent crust from the surface of the vascular structure into which the extravasated blood beneath had been converted by the process of organization, when I exposed a little spherical cavity about as big as a pea, containing brown serum, forming a sort of pocket in the living tissues, which, when scraped with the edge of a knife, bled even at the very margin of the cavity. This appearance showed that the deeper portions of the crust itself had been converted into living tissue. For cavities formed during the process of aggregation, like those with clear liquid contents in a Gruyère cheese, occur in the grumous mass which results from the action of carbolic acid upon blood; and that which I had exposed

had evidently been one of these, though its walls were now alive and vascular. Thus the blood which had been acted upon by carbolic acid, though greatly altered in physical characters, and doubtless chemically also, had not been rendered unsuitable for serving as pabulum for the growing elements of new tissue in its vicinity. The knowledge of this fact is of importance ; as it shows that, should circumstances appear to demand it, we may introduce carbolic acid deeply among the blood extravasated in a limb, confident that all will nevertheless be removed by absorption. A few days later all traces of the little cavity had become obliterated by the granulating process.

At the close of the third week the application of carbolic acid to the crust was discontinued, and the original internal pasteboard splint padded with cotton was again employed, instead of the tin and fomentation. What remained of the crust was still kept protected with the tin cap, with the view of ascertaining how long it would continue to adhere ; and at length, nearly four weeks after the accident, I tore it off from the vascular surface beneath, which bled as I did so. The crust had preserved the subjacent parts from disturbance as effectually as if it had been a piece of living integument ; and it is worthy of remark that the vascular surface below had not the pulpy softness of granulations, but was comparatively firm and substantial. The bit of crust still smelt of carbolic acid, though none had been applied for five days.

At the expiration of six weeks from the receipt of the injury the fragments were found firmly united in good position, just as if the fracture had been a simple one, though the cicatrization of the rather extensive sore was not complete till a later period.

Case 4.—James W——, aged ten, was engaged in a turner's factory worked by steam power on the 8th of June, 1866, when his right arm was drawn in between a strap and a shaft turned by it. He called out for assistance, but thinks two minutes must have elapsed before the machinery was stopped, and during the whole of this time the strap, which was still moving while he held the arm steady, was cutting into the ulnar side of the forearm, breaking through the ulna about its middle, while the radius was bent with ‘ green-stick ’ fracture. He was taken at once to the infirmary, where the wound was found to be about an inch and a half in depth, occupying more than half the circumference of the limb, chiefly at the dorsal aspect, but extending round also to the palmar side. The upper fragment of the ulna was protruding about an inch, and two strips of muscle, about a quarter of an inch in thickness and from two to three inches in length, were hanging out ; the lacerated state of the parts confirming the boy's account of the accident.

On seeing him about two hours afterwards, I sawed off the protruding portion of the ulna, and the tags of muscle having been previously clipped away, I applied carbolic acid freely to the whole interior of the wound, including the exposed surface of the bone ; and having straightened the radius, which gave way during the process, placed the limb upon a wooden palmar splint. Avoiding any attempt to approximate the lips of the wound, I covered it with a piece of sheet-tin, sufficiently large to overlap the sound skin about a quarter of an inch in every direction. The limb was fixed to the splint by a bandage, so arranged as to permit the removal of the tin without disturbing the apparatus ; and hot fomentations were applied over the whole. A few minutes after the carbolic acid was applied he said he was perfectly easy. At seven o'clock he asked for food, and took it. His pulse was then 84. At eight p.m. I saw him again, and applied beneath the tin a piece of lint dipped in carbolic acid, about as large as the wound. Noticing some distortion in the upper arm, I found that the humerus also was broken in its lower third, and applied splints accordingly, the limb being kept supported upon a pillow beside him. He slept a good deal during the night, though moaning and starting occasionally. Next day his pulse was 108 ; but he took his breakfast heartily, and the tongue was healthy, while he complained only of a little uneasiness about the elbow, and even this disappeared on changing the fomentation cloth. A piece of sheet-tin was now arranged so as to form a sort of cover for the forearm, including the hand. Being retained in position by looped bandages, it increased the steadiness of the limb, while it ensured efficiency of the fomentation.

Two days after the accident the oozing of blood and serum, which had been considerable during the previous twenty-four hours, had nearly ceased ; but he still experienced comfort from the fomentation, though any pain which he felt was connected with the simple fracture of the humerus. His pulse was 88 ; his tongue clean and appetite good after a sound sleep at night ; and from this time onward his general health continued perfectly satisfactory. On the fourth day a small quantity of pale, grey, slimy discharge was observed from beneath the crust at one part ; and thinking that this might, perhaps, have occurred for want of proper action of the carbolic acid, I applied the latter with unusual freedom to the surface of the crust. This was repeated at night ; and the same energetic use of the carbolic acid, twice in the twenty-four hours, was continued on the fifth day. Yet, on the sixth day, the discharge from beneath the crust, instead of being diminished, was increased, and more puriform to the naked eye ; while, under the microscope, there was clear indication of new cell-formation, whereas, on the day before, nothing but fibrinous material, with granular and other débris, had been discoverable. On the seventh day

the discharge was still greater in amount ; yet the limb remained free from pain, and was steadily diminishing in circumference, and pressure in the neighbourhood of the crust failed to induce any increase of the discharge, which appeared to be merely superficial.

In the course of the next few days it became apparent that this discharge, so far from being the result of insufficient action of the carbolic acid, was caused by the stimulating influence of the acid itself, applied with greater freedom over a crust much thinner than that of Case 3. Suppuration from this cause is, however, productive of no mischief, as will be better understood from the sequel. That such was the case in this instance was manifest on the fourteenth day, when the crust, which was nearly detached, was removed, disclosing an appearance for which I confess I had not been prepared. In place of the deep and ragged wound was a granulating sore, nearly on a level with the skin, and pretty uniform in surface, except at one part about its middle, where there was a depression about half an inch in depth, at the bottom of which a small portion of the outer surface of the ulna was visible, bare, but of pink colour. Not only had the compound of blood and carbolic acid which had existed in the depths of the wound been organized, but the portions of tissue killed by the violence to which they had been subjected in the accident, and also those destroyed by the caustic action of the carbolic acid, had been similarly acted on, and all had been, so to speak, fused together into a living mass, without the occurrence of any deep-seated suppuration.

By the nineteenth day the exposed part of the bone was covered, and the depression in the sore obliterated by granulation, without any exfoliation occurring ; and two days short of seven weeks after the accident the sore was entirely healed.

The extensive loss both of bone and of the soft parts made osseous union of the ulna a matter of difficulty, and on the 5th of August the limb was placed in a starched apparatus, to promote complete consolidation, and he was soon after discharged from the hospital.

About six weeks later he presented himself at the infirmary, and the bandage was removed in my absence, when, the bone appearing firm, he was allowed to dispense with the apparatus, and was unfortunately not directed to show himself again. In the course of a few weeks, however, he appeared with the fragments again movable. The starched bandage was therefore reapplied, but when I last saw him, some weeks ago, bony union had not yet occurred. A good deal of osseous formation had, however, taken place, so that the fragments now overlapped each other ; and should the cure be still incomplete when he next shows himself, the case will be a fair subject for Bickersteth's method of

treating ununited fracture by drilling. Meanwhile, the radius being firm, and the injured extensors of the fingers having completely regained their powers, he will, in any event, have a very useful hand.

This case indicated a greater range of applicability of the treatment by carbolic acid than I had anticipated, and encouraged me to employ it under the almost desperate circumstances of the following case.

Case 5.—Charles F——, a fine, intelligent boy, seven years of age, was knocked down at eight p.m. on the 23rd of June, 1866, by an omnibus crowded with passengers inside and out, and one if not both wheels passed over his right leg, breaking both the bones and inflicting a frightfully extensive wound. The person who brought him to the infirmary said that he had lost a great deal of blood, and the presence of a compress in the ham, placed there by the medical man who saw him at the time of the accident, corroborated this statement. When I saw the child, after an unavoidable delay of three hours, he was greatly prostrated by shock as well as haemorrhage, so much so that amputation appeared likely to afford but a slender chance of life, although the state of the injured parts seemed at first sight to admit of no alternative. The tibia, which was broken about its middle, lay exposed in a wound occupying almost the entire length and breadth of the inner aspect of the leg, reaching from the inner condyle of the femur to within an inch and a quarter of the tip of the internal malleolus; the skin having been stripped back so as to lay bare the gastrocnemius as well as the bone. The large flap of integument was perforated about two inches from its edge opposite to the seat of fracture, and there was also an opening in the skin on the outer side of the leg, implying that the violence had acted with full effect upon the whole thickness of the limb. Yet the bone was not comminuted, and the muscles, though evidently severely contused, were not much lacerated, while the anterior tibial artery was felt beating in the foot; and, hopeless as would have been the idea of trying to save the limb by ordinary treatment, I determined to make the attempt by the help of carbolic acid.

Chloroform having been administered, the acid of full strength was applied with great freedom, the contused mass being repeatedly squeezed, to induce the liquid to insinuate itself into all its interstices, including that between the riding fragments of the tibia. The flap of skin was then brought towards its natural position, and lint soaked in the acid was placed upon the wide raw surface which still remained exposed, and over the lint a piece of sheet-tin. The other openings in the integument were similarly treated; and, the riding of the fragments having been corrected by extension, the limb was laid on its outer side, with the knee bent, upon an external pasteboard splint, moulded

to the leg and foot, and strengthened by a temporary wooden splint. A porous cloth was applied over the tin to absorb the blood and serum which must escape from beneath its edges ; and the whole apparatus was secured with a roller. At the conclusion of the dressing the pulse was 112.

He passed a restless night, though occasionally dozing, and the pulse next morning was 120. The bandage having been cut away sufficiently to enable the tin to be removed, the wound was found to have gaped so that the lint no longer covered the whole of it. Pieces of the cloth, which had become soaked with the exuded blood, were placed upon the exposed part, and also over the lint so as to make the crust more substantial, and the whole was freely treated with carbolic acid. The tin was then bulged out so as to be accommodated to the thickened crust, while overlapping the neighbouring skin to a slight extent ; being retained in position by a couple of turns of bandage. A hot fomentation was then placed upon the inner aspect of the limb, and the whole leg enveloped in a large sheet of block-tin secured by looped bandages.

In the evening the pulse was 136, and on the following morning, thirty-six hours after the accident, it had risen to 168, and was very weak. He lay talking to himself in a rambling manner, unable to understand what was said to him. He was extremely restless, and had taken no food whatever since his admission. During the next night, however, he became composed, and took a little milk ; and on the morning of the third day he was found to be again intelligent, while the pulse had fallen to 140, and was of fair strength. The skin in the vicinity of the injury, both at the knee and ankle, was free from discoloration or swelling ; but part of the large flap of skin over the calf was of purple tint, and had evidently lost its vitality. This dead part was touched with carbolic acid, to preserve it from decomposition, and convert it into a crust for the protection of the subjacent textures, and an additional piece of tin was applied to cover it. A good deal of brown transparent fluid escaped from beneath the crust.

On the fourth day the pulse was 120 ; he was quite bright and tranquil, and said he felt no pain. There was still no odour about the injured part, except that of carbolic acid. The discharge was much diminished, and was principally serous.

By the sixth day the pulse was as low as 108. He had a hearty appetite, and also took with avidity the six ounces of port wine allowed him during the twenty-four hours. His tongue, which had previously been dry, was moist. He had slept well at night, though waking occasionally with a scream. The discharge from beneath the crust, trifling in amount, was chiefly serous.

On the eighth day the splint was removed for the first time, and was covered with sheet-tin in order to prevent the discharge from softening the pasteboard.

The leg had become slightly bent inwards through the yielding of the splint; and when it was now straightened, the upper margin of the crust became detached, exposing a deep granulating cavity. A bit of lint, dipped in carbolic acid, was applied lightly over this opening, and the tin was readjusted so as to cover it. Pressure in the neighbourhood of the injured part, about the knee, ankle, and calf, failed to induce the slightest increase of the discharge, which was thus shown to come merely from the surface beneath the crust, and was still for the most part transparent.

At the close of the second week his state was on the whole very favourable. His general health was much improved; and although he still suffered occasionally, especially at night, from restless movements of the limb, these had been much restrained by a new splint, extending from half-way up the thigh to the toes. The wound was certainly very large, measuring eight inches in length by six in greatest width; but it was healing round almost the entire circumference. In order to permit cicatrization, which carbolic acid tends to check, the detached edges of the crust had been clipped away, and the exposed narrow ring of granulations was dressed with lint dipped in a solution of sulphite of potash—five grains to an ounce of water. The crust, however, was still touched daily as before with carbolic acid, while the tin still covered the whole of the injured part. By this means it was intended that cicatrization should be allowed to go on, and yet decomposition of the discharge be prevented; and this seemed to be to a great extent, if not entirely, attained.

There was, however, one unfavourable circumstance. The little sore on the outer side of the leg, which had been dressed separately without carbolic acid, and had for some time been observed to be increasing rather than diminishing, now assumed unmistakably the appearance of a mild form of hospital gangrene, and became blended with the main sore. For two days an attempt was made to correct the disease by touching the affected part with nitric acid; but on the eighteenth day it was clear that some more effectual measures must be adopted, as the skin in the vicinity had become insidiously undermined to a very serious extent. Accordingly I placed the boy under chloroform, and scraped away with a spoon all the soft grey sloughs, slitting up the skin in order to gain access to them, and in some parts clipping portions of it away, and then applied the strongest nitric acid thoroughly to the bleeding surface. As the disease extended up to the anterior edge of the crust, I thought it right to examine the state of the parts beneath, and as it was pretty loose I removed it. And now a sight presented itself which filled me with horror. There was, indeed, no appearance of hospital gangrene in the parts which the crust had covered, the granulations there having the florid aspect of perfect health; but in the

large sore lay the lower fragment of the tibia, freely exposed to the extent of two inches and a half in length, bare and white like a macerated bone. At the upper end of this fragment, and apparently for a considerable distance from it, the bone was thus denuded round its entire circumference ; and, judging from previous experience, there was reason to expect that, even if the patient should survive the profuse suppuration which was to be anticipated, about two inches of the whole thickness of the tibia must exfoliate, an amount of loss which in the child's small limb, would of necessity render it utterly useless. The upper fragment was also bare for about half an inch just above its extremity, but the end itself was covered with prominent granulations.

Though despairing of any good result, I resolved to watch for a while the progress of events, prepared to amputate as soon as the boy's health should show signs of failing ; and comforting myself with the reflection that he had been brought into a state greatly more favourable for the operation than on his admission. In order to keep down the amount of the discharge the sore was dressed with the sulphite-of-potash lotion, a poultice being applied to the part which had been treated with nitric acid. When the sloughs caused by the caustic separated a healthy surface appeared, which in the course of the next ten days was nearly healed. In other parts of the sore, however, grey patches occasionally showed themselves, assuming healthy characters after being touched with carbolic acid, which, when efficient, has the advantage over other caustics of being painless. But at length spots of hospital gangrene appeared in a form no longer amenable to this mild treatment, in spite of which they began to extend rapidly, and on the 26th of July it became necessary to put the child again under chloroform and apply nitric acid in the same thorough manner as before. This had the effect of producing a perfectly healthy state of the whole sore, which proceeded to heal with great rapidity ; so that by the 8th of August it was found to measure an inch less in length and two inches less in greatest breadth than at the time when the crust was removed.

In the meantime his general health, instead of deteriorating, had improved, and he was evidently regaining flesh, while the discharge of pus was astonishingly little considering the state of the limb, being barely sufficient to soak the single layer of lint that covered the sore.

The explanation of this satisfactory state of things was afforded by an observation of much interest made at this period. Since the removal of the crust the granulations had been growing up on all sides about the bone, so that the bare part of the upper fragment was almost entirely covered in, and even the lower fragment, which projected beyond the level of the upper, was to a great extent embedded in the new growth. It had been noticed before the end of

this fragment was so much covered up, that granulations were sprouting from the medullary canal, showing that the bone was not dead in its entire thickness. Nevertheless, as the superficial parts had certainly lost their vitality, I had not doubted that a thin layer at least must exfoliate from the whole. Now, however, I observed that some of the surface which remained exposed had assumed a pink colour, implying that the layer of dead bone, whatever its thickness might have originally been, had become so thin as to be transparent, through absorption by new tissue growing in the interior. Further, on attempting to pass the eyed end of a probe between the tibia and the granulations which had enveloped it, I found to my surprise that the instrument could only be introduced for a very short distance, the granulations, with the exception of a narrow free border, being everywhere adherent. The new tissue outside the bone had coalesced with that within, after complete absorption of the intervening dead stratum. Hence the remarkable absence of discharge from around the bone.

During the following month I was absent from home, but was informed that the same process was for some time continued: the granulations gradually encroaching more and more on the exposed bone, and adhering to it as they advanced. The upper fragment was thus entirely covered without any exfoliation occurring, and the bare surface of the lower fragment was reduced to comparatively small dimensions. On the 10th of September the remainder of the dead part, being loose, was removed without difficulty as an exfoliation. It was about an inch in greatest length; but was of extremely irregular shape, full a quarter of the circumference of the tibia being deficient. At the upper end, where it had been most prominent and had become discoloured, it had nearly the full thickness of the dense tissue; but towards the lower end it became thinned away, so as to be in some places as delicate as tissue-paper. The outer surface presented near the margin an appearance of especial interest, being at some parts, even where the bone had considerable thickness, variously scooped and bevelled in a manner that admitted of no other explanation than that the granulations overlapping the dead bone externally had been engaged in its absorption. On applying a magnifier to these excavations in the external surface, they were seen to present a peculiar velvety aspect, differing from the rest of the exterior, but resembling the internal parts of the exfoliation.

The only observation at all analogous to this with which I am acquainted is that of the effects produced upon the ivory pegs used in Dieffenbach's method of treating ununited fracture, the parts of the pegs driven into the bone having been observed, when removed, to have suffered diminution in size. This has hitherto remained as an isolated fact, and it has been regarded as an axiom in

surgery that a piece of bone once dead must all come away as an exfoliation. Why it was that in the case before us the osseous tissue destroyed by external violence, aided by the action of carbolic acid, was so exceptionally affected by surrounding parts, the granulations in its vicinity discharging the office of absorbents of the dense tissue, instead of forming pus like those around an ordinary exfoliation, I will reserve for future discussion, when I shall have occasion to point out the great importance of the fact in its bearing both on pathology and practice. Meanwhile I may remark that it illustrates beautifully the function of absorption, which, even where solid substances are taken up, does not require any special set of absorbent vessels, but may be effected even by granulations, the most rudimentary of all tissues, each cell feeding upon any suitable substance in its vicinity.

We also see at once the value of the observation with reference to the treatment of compound fracture with carbolic acid ; for it shows that in cases in which the bone is exposed, the acid may be applied so freely as to cause death of its tissue without necessarily inducing exfoliation.

The case was now reduced to one of simple fracture with a large granulating sore, and this was greatly diminished and healing rapidly, while the union of the fragments was becoming very firm ; and the limb would doubtless soon have been entirely sound had it not been for that cruel scourge, hospital gangrene. This, however, had shown itself ten days before the removal of the exfoliation, not in the sore, but about an inch from its edge, as a pustule in the cicatrix, which on bursting disclosed a grey slough that soon showed its characters unmistakably, producing considerable destruction of the scar, although the original sore continued to heal kindly.

I will not enter into the history of this and numerous subsequent attacks of the disease further than to state that they were partial in their effect, the unaffected parts still healing with rapidity, and that they continued to yield to the treatment with nitric acid ; so that at one time the whole sore was very nearly healed.

But in the early part of October the disease assumed a more intractable form, and in spite of the most energetic use of nitric acid on several occasions, which produced illusory appearances of temporary improvement, by the 27th of the month the sore had become enlarged to nearly its original dimensions, while the limb had swollen greatly through inflammation caused by the irritation, and the boy's general health was rapidly giving way under the increased discharge and nervous excitement.

The question of amputation now again presented itself, but a good airy room in a different department of the hospital being happily now at my disposal,

I determined to give the limb one last chance. Before he was taken to the new ward, nitric acid was once more thoroughly applied. His nurse was directed to change the poultice every three hours, and he continued to take wine and some tonic medicine. His general health immediately improved, and when the slough separated, the sore looked healthy. It was now dressed with lint dipped in a solution of sulphate of copper, five grains to an ounce of water, and over this a poultice, the whole being changed every three or four hours night and day; and under this treatment cicatrization proceeded rapidly. Yet when the scar had attained a certain width, a tendency to vesication again showed itself, threatening recurrence of the disease, and in order to prevent the newly formed epidermis from acquiring poisonous qualities as it seemed to do, I ordered the lint with the lotion, as well as the poultice, to be extended over the whole cicatrix. From the time this dressing was adopted the progress was uninterruptedly satisfactory till the 9th of January, when the sore was at length entirely healed, and he was allowed for the first time to put his foot to the ground. The contraction of the large cicatrix, involving at one part the gastrocnemius muscle, had caused some bending of the knee and pointing of the toes. The former has since become corrected spontaneously by his habitual attitude, sitting in bed with the legs extended before him. The pointing of the toes has also become diminished, and will probably soon pass off entirely, without the division of the tendo Achillis, which I had in view. The tibia, which has long been firm, is of precisely the same length as the other, and the contour of the limb is natural. His general health also is excellent; but he was detained in the hospital till the 9th inst. (March 1867), on account of an obstinate eczematous eruption on the integument of the leg irritated by the long-continued poulticing.

Case 6.—The following case terminated fatally, but from circumstances of an accidental nature; and I trust that the instruction to be derived from it will not be interfered with by the unhappy ultimate result.

John C——, aged fifty-seven, a labourer, was working in a quarry at Row, near Helensburgh, on the Clyde, at nine a.m. on the 26th of October, 1866, when, striking with a crowbar an overhanging part, he brought down an enormous mass of stone weighing six or seven tons, which fell in large blocks on and about him. His right thigh-bone was broken in its lower third, and, as afterwards appeared, the end of the upper fragment was driven through the skin at the inner aspect of the limb a little above the knee. The right collar-bone was fractured at the same time, and he was severely contused in other parts. It was long before his only companion in the quarry could extricate him from

his position, and the procuring of a conveyance involved further delay ; so that a considerable period elapsed, during which he lost much blood from the thigh, before he could be taken to Helensburgh. Here he was placed on a litter, with a warm moist blanket round the limb, with the object, as he said, of checking the bleeding, which, however, it could not but tend to encourage. He was then conveyed by train to Glasgow, where he reached the infirmary six hours after the occurrence of the accident.

Dr. Archibald Cameron, the house surgeon, seeing the case to be a very grave one, at once sent for me, but without any delay introduced carbolic acid into the wound by means of a piece of lint held in a pair of dressing forceps, passing it about an inch in every direction beneath the integument, after squeezing out a considerable quantity of extravasated blood from the orifice, which was large enough to admit the tip of the finger.

On arriving, an hour after the patient's admission, I found him in a state of prostration sufficiently explained by the severity of his injuries and by the blood lost to the circulation, including a large amount extravasated in the limb, and distending, not only the whole thigh, but the calf, the tenseness of which contrasted strikingly with the flaccidity of the other.

Under these circumstances decomposition of the blood effused among the tissues would have been necessarily fatal. And yet, considering the length of time that had elapsed since the receipt of the injury, and the fact that a reeking flannel had been for two hours in contact with the wound, and had already a somewhat offensive odour when removed from it, there seemed but a poor chance for the treatment with carbolic acid. On the other hand, taking into account the man's time of life and general condition, I believed that to amputate through the thigh infiltrated with blood would be certainly to kill him. And therefore, as it was impossible to say that the other treatment had no chance, while, if it should prove successful, it would have the immeasurable superiority of saving limb as well as life, I determined to persevere with it.

Having removed from the wound the dressings placed on it by Dr. Cameron, I forcibly squeezed out a further large amount of blood, and applied carbolic acid in lint and also mixed with blood, so as to provide for a crust of considerable thickness overlapping the skin by about half an inch every way. This was covered with a circular piece of tin, two inches across, well bulged out except a flat margin about a quarter of an inch wide, which rested on the surrounding integument. This tin cap was retained in position by a single turn of bandage tied round the limb.

The lower end of the upper fragment was much displaced downwards in the vicinity of the wound, but returned towards its natural position on extension

of the limb. There still remained considerable depression anteriorly over the seat of fracture; but the lower fragment did not seem to project towards the ham so much as to forbid the use of the long splint. This I accordingly employed with two interior splints to support the muscles of the thigh, one of Gooch's material on the outer aspect, the other a large sheet of stout block-tin, embracing the anterior, inner, and posterior aspects of the limb to a little below the knee, padded in the first instance with a dry towel, for which a hot fomentation should be substituted when all tendency to haemorrhage should have ceased. The object of having the tin extend round the back of the thigh was that it might prevent the discharges from soaking into the bed beneath; and in this way it proved extremely useful.

He passed an uneasy though not entirely sleepless night, suffering more from his shoulder and bruised side than from the thigh. Next morning his aspect was favourable, the pulse 76, and tongue natural; he took a little tea for his breakfast, but nothing solid. The tin cap having been removed, care being taken to avoid detaching the crust along with it, carbolic acid was applied to the surface of the latter. A hot fomentation cloth was then placed on the inner side and front of the thigh and gave him great comfort, and when the dressing was completed he was quite easy. The interior splints being kept in position by looped bandages, and the long splint by the usual folded sheet fixed by pins, along with the perineal band and handkerchief round the foot, the fomentations could be changed night and morning without any disturbance of the limb.

The following night he had a good deal of sleep, the thigh not causing him any inconvenience; and next day, the third after the accident, he took solid food with relish. His pulse was 72, and his tongue continued moist, though he was somewhat thirsty. The crust was touched again with carbolic acid, and covered with a circular piece of calico to prevent the tin cap from adhering to it. He still found comfort in the fomentations.

On the fourth day he made a substantial breakfast after a good night's rest, and was not so thirsty. There was, however, now seen for the first time a slight blush of redness on the front of the thigh over the seat of injury. This was on the fifth day somewhat increased, and the thigh and calf were both more swollen. The tongue also was slightly furred at the base, and his appetite was not quite so good.

On the sixth day the dimensions and appearance of the limb were unaltered, but on the seventh both the redness and swelling were distinctly diminished.

By the end of the second week his appetite was improved and his pulse was 76; while there had not been a drop of discharge from beneath the crust,

which had been still touched daily with carbolic acid, the fomentations also having been continued. The swelling, however, had not subsided, and the redness, though varying in extent and degree, had never disappeared from over the seat of fracture. On the fifteenth day a defined prominence made its appearance at this part in a space about as large as the palm of the hand, a little further forward than the crust, and a sense of fluctuation was to be perceived in it. In the evening Dr. Cameron, on changing the fomentation, saw more pus than he thought could be accounted for by the superficial excoriation round the crust, and next morning, on removing the flannel, I found it soaked with similar discharge ; a considerable quantity also lying between the tin splint and the limb. On raising the tin cap, the matter was seen welling out from beneath the lower edge of the crust. It was perfectly free from odour, confirming the conclusion I had previously arrived at that this abscess was not in any way caused by decomposition from atmospheric influence. The long period that elapsed before it made its appearance, together with the absence of any serious constitutional disturbance, clearly showed that the carbolic acid had effectually answered the purpose for which it was applied, the constant oozing of blood from the small wound having doubtless been in the patient's favour, by preventing decomposition from penetrating far into the interior before he came under treatment. We know that a mass of extravasated blood occasionally becomes the seat of suppuration without the existence of any external wound. A curious instance of this occurred lately in my practice, in a boy who fell down the hold of a ship upon his head, and, besides serious cerebral symptoms, exhibited at once a remarkable prominence of the right eyeball, evidently due to extravasation of blood into the orbit. There being no wound, I expected that the blood would be absorbed; but after the lapse of several days, the prominence of the eye showed increase rather than diminution, and the boy began to complain of supraorbital pain. Fluctuation then became perceptible, and pus was evacuated by incision, after which the eyeball gradually resumed its natural position.

Such I supposed to be the nature of the abscess in C——'s case, and previous experience made me fear that, if decomposition of its contents should occur, the irritation of the fetid pus might cause very serious consequences from rapid extension of suppuration among the imperfect and feeble products of the organization of the blood in the yet swollen limb.

Hence I had intended to evacuate the matter by aid of carbolic acid in such a way as to prevent decomposition. As the abscess was not near the surface at the part where it appeared to be pointing, I had reckoned on having plenty of time for my operations, and was greatly disappointed to find that it had discharged itself spontaneously.

Nevertheless, as the pus was proceeding from beneath the crust impregnated with carbolic acid and was still quite odourless, I did not altogether despair of attaining my object. In order to make the crust more effectual, I extended it for about three-quarters of an inch at the part from which the pus was escaping, by a piece of lint dipped in carbolic acid, which, when mixed with pus, forms a sort of curdy mass which answered pretty well for a crust. A considerable quantity of matter, of moderate consistence and greenish-white colour, was then pressed out from the limb. A new tin cap having been made, large enough to cover the whole of the extended crust, the fomentation was continued as usual.

Next day it was evident, from the sense of fluctuation, that reaccumulation had occurred in the abscess, but no further discharge had taken place. On removing the tin cap, however, pus was seen to well out from a new situation at the upper edge of the crust. A piece of lint dipped in carbolic acid was at once placed on this part, and the matter was pressed out and carefully collected measuring 3 oz., of moderate consistence and yellowish-white colour, still without odour except that of carbolic acid. The crust having been somewhat extended at the situation of the new opening, the whole was freely treated with carbolic acid, the tin cap readjusted, and fomentation continued.

During the rest of the week that followed the first evacuation of the abscess the same treatment was pursued with the most satisfactory results. Some pus was usually seen on the fomenting flannel both morning and evening, and some was pressed out of the limb from the orifice last formed, but the amount rapidly diminished in quantity, and also became thinner and more transparent, while it continued free from odour. It may be worth while to mention in detail the quantities obtained from the limb in the morning of each of these days. On the seventeenth day it was an ounce and a half, somewhat thinner than before; on the eighteenth, two drachms and a half, decidedly thinner; on the nineteenth, half a drachm, much thinner and more transparent; on the twentieth, a quarter of a drachm, similar in quality; and on the twenty-first, six drops only, and almost free from opacity. Finally, in the evening of that day no discharge was seen on the flannel, nor could any be squeezed out from the limb. Meanwhile the calf, which had increased markedly in circumference just before the abscess opened, steadily diminished, and in the thigh all swelling disappeared from over the seat of fracture, so that the end of the upper fragment, previously quite obscured, could be distinctly defined. His general health, too, had improved; his tongue had become quite clean, and he had acquired for the first time since his admission a genuine appetite, the pulse continuing about 72.

I suspect, however, that this success made us relax a little our vigilant

care in guarding against decomposition. But be this as it may, the method which we pursued in order to avoid it was not, as experience has since shown, thoroughly trustworthy. Would that I had at that time known of the mode of proceeding which will be found described in a future section of this communication. Very different then might have been the issue of the case !

On the twenty-second day pus was again found in the flannel, and some bubbles of gas were observed to escape along with the two or three drops that could be squeezed from the limb, and these had a distinctly offensive odour. Judging it now useless to retain the crust any longer, I removed it, and found the original wound still sealed by the original clot, the openings by which the pus had escaped being new apertures in the skin overlapped by the crust. In the after-part of the day he had a good deal of uneasiness, and in the evening half an ounce of pus, with numerous air-bubbles, was pressed out of the limb by Dr. Cameron. After this the patient passed a comfortable night, and in the morning only two drachms of matter could be procured from the thigh, but this was thicker and more opaque than it had been, with decidedly offensive odour, and contained bubbles of gas ; there was also pus in the flannel. There was, further, some return of swelling over the seat of fracture.

But though the plan of dealing with the abscess had failed to accomplish all that I desired, its essential object appeared to have been attained. For during the week in which decomposition was prevented, the thigh had become so much consolidated and strengthened that all danger of serious consequences seemed to have been tided over. No extension of the suppuration took place beyond the trifling degree above described, and his constitution did not suffer. Any further use of carbolic acid being obviously uncalled for, the sore was simply dressed with a lotion, the lint being so arranged as to allow free escape for the pus, and afterwards, to promote this more effectually, a small perforated caoutchouc tube was introduced, a dry cloth being substituted for the fomentation. Under this management the discharge gradually diminished in quantity, and became again thinner and more transparent, and the swelling of the calf became steadily reduced.

Still the opening did not close, and on the 2nd of December, more than a fortnight having passed in this way, I introduced a probe, and found that it passed downwards to bare bone, including a considerable extent of surface in the lower fragment. Here, then, was presented the prospect of a tedious process of exfoliation ; whereas if decomposition of the pus had not occurred, the granulations would probably have closed upon the dead bone, and absorbed it, as in the last case, and the fact that any part had lost its vitality would then never

have been known. That there is a reasonable ground for this belief will, I trust, appear from the discussion in the succeeding section.

For a long time the progress of the patient continued satisfactory, the process of union of the fragments advancing steadily, till in the early part of February, the bone being firm, the splints were entirely discarded, and the case was reduced from one of fracture to one of limited exfoliation. It was satisfactory also to find that the knee-joint continued movable, so that I confidently anticipated recovery, with a perfectly useful limb.

At this period, however, a new symptom presented itself—viz. haemorrhage from the sinus. Mr. Hector Cameron, my present house surgeon, who saw the first appearance of bleeding, supposed it to proceed from the surface of the granulations ; for it was then small in amount, and ceased spontaneously. Some days later, however—viz. on the 11th of February—a very profuse haemorrhage occurred, the blood soaking through the bed, and dropping upon the floor beneath, before it was observed, and the gentleman who was summoned to see the patient in Mr. Cameron's absence, found him pulseless. He afterwards rallied to some extent, but remained utterly prostrated, and unable to retain the slightest nourishment. As the popliteal artery could be felt beating in the lower part of the ham, I hoped that the source of the blood might be some minor branch, which might possibly close. But it afterwards appeared that a circular opening existed in the main vessel, occasioned no doubt by the pressure of an irregular projection of the lower fragment. It would be irrelevant to relate particularly the history of his yet further exhaustion by recurrent haemorrhages after delusive temporary cessations, or of my attempts to restore him by tying the popliteal artery, and making arrangements for transfusion, to which he declined to submit. He died on the 25th of February.

The next four cases occurred in the practice of my colleagues in the infirmary, who have kindly placed them at my disposal.

Case 7.—Mary M——, aged sixty-two, was admitted under the care of Dr. Morton on the 13th of August, 1866, at eleven p.m., when she stated that about five o'clock in the afternoon of that day she missed her footing when going downstairs, and fell with violence, and on getting up found that her right forearm was broken and bleeding. A medical man was called in, who made various applications in order to stop the haemorrhage, but failed to do so, and she was advised to go to the infirmary. Mr. A. T. Thomson, the house surgeon (to whom I am indebted for notes of the case), on removing the bandage, from which blood was trickling, found both bones of the forearm broken a little above the wrist, and a detached fragment of the radius projecting from a

wound about as large as a fourpenny-piece, on the outer aspect of the limb. Having extracted this fragment, he applied liquid carbolic acid thoroughly to the interior of the wound. This rather increased the bleeding, which, however, he arrested completely by plugging the orifice with a bit of lint dipped in the acid. Over this he placed a mixture of blood and carbolic acid, covering it with a piece of dry lint. He then put up the limb in two well-padded Gooch's splints, retained in position with a continuous bandage. The apparatus was left undisturbed for five days, when, on removal of the splints, it was found that the piece of dry lint over the wound, though it had been saturated with blood, was quite dry, having become incorporated with the crust beneath. It was not interfered with except that the surface was touched with carbolic acid, and the splints were reapplied as before, the part being quite free from uneasiness.

On the twelfth day the splints were again removed and the crust was detached, when it was found that the piece of lint with which the wound had been plugged had become partly pushed out of the orifice. The plug also was now removed, when the surface beneath was observed to be granulating, but entirely free from pus. The sore was dressed with one part of carbolic acid to seven parts of olive oil applied on lint every second day, the use of the splints being continued till the 8th of September, when she was discharged, with the sore healed and both bones firmly united, two days less than four weeks after the accident.

This case is valuable as an example of a mode in which troublesome bleeding in compound fracture may sometimes be advantageously arrested. The entire absence of pus about the plug on the twelfth day after its introduction contrasts strikingly with the suppuration invariably caused within four days by a piece of lint inserted without carbolic acid into a wound.

Case 8.—Samuel B——, aged thirteen, was admitted under Dr. Morton's care, on the 30th of August, 1866, with a compound fracture of the left femur, about the junction of the upper and middle thirds of the shaft, and a simple fracture of the right thigh in a similar situation. He stated that about four hours previously he was engaged in some work about a steam-engine, when he was struck by one of the balls of the 'governor', and hurled with great force against an iron pillar. The men who brought him to the infirmary said that when he was raised from the ground a piece of bone was seen to protrude from a wound in the left thigh, but was restored to its natural position by a medical man who was called in to see him, and who applied a long splint and bandage to each limb. Mr. A. T. Thomson, on examining the boy, found a lacerated wound

about three inches long at the upper part of the left thigh, running transversely from the middle of the inner side of the limb to its posterior aspect, and in this wound the upper fragment of the femur was visible, somewhat displaced, but not protruding. There was some bleeding, but not to any serious extent. He sponged out the wound thoroughly with a solution of one part of carbolic acid in three parts of olive oil, and then covered its lips with a mixture of blood and the undiluted acid spread upon lint, and over this a piece of sheet-tin, retained in position by means of a looped bandage. He next corrected the faulty position of the fragments and applied lateral splints of Gooch's material to the thigh, maintaining gentle extension by means of plasters applied to the integument of the leg after the American plan, and fixed to the foot of the bed, a perineal band being attached to the bed-head. While the left limb was thus kept readily accessible for changing the dressings, the long splint was employed as usual for the simple fracture on the right side.

Next day the surface of the crust was touched with carbolic acid, and a hot fomentation applied to the limb.

On the third day the crust was removed through a misunderstanding, but it was resolved to follow out the treatment on the same principle, and with this view the wound was dressed twice a day with lint dipped in the mixture of carbolic acid and oil (one part to three), covered with the tin, as the crust had been before, while the fomentations also were continued. Meanwhile the limb remained free from pain, redness, or swelling, and there was a complete absence of constitutional disturbance.

On the sixth day, however, he was a little feverish, and remained so, though without any apparent local symptoms, till the twelfth day, when Mr. Thomson noticed that the central part of the wound, which had become covered with a whitish crust, was somewhat prominent, and, on careful examination, perceived a distinct sense of fluctuation. He therefore removed the white layer from that part, when eight ounces of perfectly odourless pus escaped. A probe introduced failed to detect any bare bone. Mr. Thomson now sponged out the cavity of the abscess with the mixture of carbolic acid and oil, and left in it a strip of lint dipped in the same, continuing the other dressings as before. The constitutional disturbance now at once subsided, and under the same dressing the cavity of the abscess quickly contracted, and in a little more than a fortnight closed entirely. Six weeks after the accident the wound was completely healed, and both the thigh-bones were firmly united, with the limbs of equal length. In another week he was able to stand.

This case, which, I cannot avoid remarking, reflects great credit on the house surgeon in charge, is interesting as another instance of the occurrence of

abscess in compound fracture, independently of atmospheric influence. That it was so in this instance is clearly shown by the entire absence of constitutional symptoms for the first five days, the circumscribed character of the suppuration, and the odourless nature of the pus. The injured part suppurated, probably from the same cause as a severe bruise may without any breach of the integument. The satisfactory results obtained by treating the wound with carbolic acid diluted with oil, instead of the undiluted acid, will naturally suggest the inquiry whether this would not always be the better practice. And I may mention that my former house surgeon, Dr. A. Cameron, met with similar success in two cases in which he pursued the same treatment—one of them a compound fracture of the ulna at the elbow, the other a severe contused wound of the back of the hand communicating with a fractured metatarsal bone. But considering how much is at stake, and that the patient's life may depend upon entire destruction of the septic germs that lie in the wound, I am inclined to think it wiser to avail ourselves of the full energy of the pure acid, more especially since we have had sufficient evidence that any caustic effects it may have are not productive of serious consequences.

Case 9.—William C——, aged thirty-three, was admitted on the 29th of September, 1866, under the care of Dr. Eben. Watson, with a compound fracture of the left tibia, produced by an omnibus passing over the limb at eight o'clock p.m. The broken part of the bone was exposed in a wound six and a half inches in length, a little above the ankle. The skin in the vicinity was detached from the subjacent tissues for about two inches, and there was ecchymosis reaching some distance up the leg, with other evidence of severe contusion.

An hour and a half after the accident Dr. A. Forsyth, the house surgeon, from whose notes these particulars are obtained, sponged out the wound thoroughly with undiluted carbolic acid, and placed over it layers of calico soaked with the acid; and, in order to provide for a sufficiently substantial crust, spread over the calico some paste composed of starch moistened with carbolic acid, covering the whole with a piece of block-tin secured with a bandage, the fracture being treated with a suitable apparatus. After the dressing, the patient, though unable to express his feelings, being dumb, appeared entirely free from uneasiness.

Next day the tin was carefully removed from the crust, the surface of which was touched with carbolic acid, and, the tin having been readjusted, hot fomentations were applied to the leg and foot. The pulse was now 96, the tongue clean, and appetite good. The same treatment was pursued till the thirteenth

day, when the fomentations were discontinued, and the edges of the crust which were loose were clipped away, and lint moistened with water was applied to the granulating surface thus exposed, the remainder of the crust being still touched daily with carbolic acid. Meanwhile there had been no suppuration beneath the crust, and the patient had remained free from constitutional symptoms.

On the seventeenth day the crust, which had separated from the wound at its lower third, was removed, disclosing a healthy granulating surface, the bone being nowhere visible, while there was no appearance of pus, except a trifling amount towards the lower part. The sore, which was entirely superficial, was now treated like an ordinary ulcer, and healed quickly. The bone also united as in a simple fracture, and he was discharged eight weeks after the receipt of the injury, having been kept longer in the hospital than would otherwise have been necessary, on account of a head affection to which he was subject.

The above case, besides being a good example of the effects of the treatment of compound fracture with carbolic acid, affords an illustration of a practice which I have on several occasions found useful when there has been but little bleeding from the wound, a dough or paste composed of flour or starch, moistened with the acid, being employed in lieu of the compound with blood to render the crust sufficiently substantial.

Case 10.—Thomas M'B——, a labourer, who gave his age as fifty-two, but had the appearance of a much older person, was admitted at noon on the 2nd of January, 1867, under the care of Dr. G. Buchanan, having been knocked down an hour before by the shaft of a luggage wagon, the wheel of which passed over his left leg, producing a compound fracture in the lower third of the limb. Mr. James Robinson, the house surgeon, who has given me notes of the case, found a wound from which blood was oozing, about an inch and a half in length, exposing part of the tibia, and communicating with the seat of fracture. The tissues were pretty severely contused. Undiluted carbolic acid was applied freely to the interior of the wound by means of lint held in a pair of dressing-forceps, and a crust was formed of blood mingled with the acid, covered with lint, over which a cap of tin was placed, well bulged out to correspond to the substantial crust, and large enough to overlap to a slight extent the sound skin in the vicinity. The fragments having been brought into proper position, the limb was put up with lateral wooden splints, with a hot fomentation. At the conclusion of the dressing the patient expressed himself as greatly relieved. The pulse was then 65.

Next day he was free from pain after a fair night's rest. The pulse was 74,

and the tongue clean and moist. The surface of the crust was touched with carbolic acid, the limb being still fomented ; and the same treatment was continued daily for the following fortnight, during which the limb was entirely free from pain, redness, or suppuration, while his constitution was quite unaffected by the injury, the tongue remaining clean, and the pulse varying only between 72 and 85.

I was present when the crust was removed, eighteen days after the accident. Not a drop of pus existed beneath it. On the contrary, the superficial sloughs of the cutis occasioned by the caustic action of the acid first applied remained still undetached. The exposed surface was treated with water dressing, and in two days presented the appearance of an ordinary granulating sore, which healed without interruption. Six weeks and three days after the receipt of the injury the splints were removed, the bones being satisfactorily united.

This is an excellent example of the effects of the carbolic-acid treatment in a compound fracture of the leg of average severity. No simple fracture could have caused less disturbance, either local or constitutional.

Case II.—The following case, though incomplete, is given on account of the conclusive evidence it affords regarding a complication of compound fracture of much interest both practically and theoretically—viz. emphysema of the limb in consequence of air being introduced into the wound, and diffused among the interstices of the tissues by a pumping action of the fragments of the broken bone when freely moved through restlessness of the patient or carelessness of his attendants before he comes under the surgeon's care. Such a state of things may seem at first sight to render it impossible to prevent decomposition of the extravasated blood, since it would be out of the question to attempt to apply carbolic acid to all the emphysematous tissues. But I have long indulged the hope that, the air entering in small successive portions, its floating organisms might be arrested by the first blood with which they came in contact, and remain for some time confined to the vicinity of the external wound, in which case, by squeezing out as much blood as possible from the orifice in the integument, and introducing carbolic acid freely, we might get rid of all causes of decomposition in the limb, the mere atmospheric gases diffused more remotely, however abundant, being entirely innocuous. This hope, it now appears, was not ill-founded.

John D——, aged fifty-five, a calico-printer, of intemperate habits, was admitted under my care in the Royal Infirmary at six p.m. on the 4th of April, 1867, having broken both bones of his right leg about an hour before by jumping out of a window into the street, from a height of between fifteen and twenty

feet, while in a state of intoxication. He was carried upstairs to his lodgings, kicking about in his drunken frenzy. A cloth was then put round the leg, but no efficient means were employed to steady it, and he was conveyed to the hospital from a distant part of the city in a cab, moving the limb recklessly during the whole journey. His friends stated that he had lost a great deal of blood, and the cloth which was round the limb on his admission was saturated. Mr. H. Cameron, the house surgeon, found a wound about half an inch in length, situated over the spine of the tibia, at the junction of the middle and lower thirds of the bone, the fracture being half an inch lower down, and obviously communicating. The wound was bleeding very freely, and the leg was considerably swollen through extravasation of blood into it. On manipulation, Mr. Cameron found the tissues about the seat of fracture emphysematous, the characteristic crackling sensation being experienced fully four inches above the wound and two inches below it, and also on the opposite side of the limb, over the fibula ; and as a result of the handling, a frothy mixture of blood and air, in larger and smaller bubbles, escaped from the orifice. The fragments were much displaced, the foot being greatly everted.

Mr. Cameron, having squeezed out as much blood as possible from the wound, introduced melted crystallized carbolic acid in a piece of calico held in dressing-forceps, which he passed in various directions for more than two inches beneath the integument and about an inch and a half among the deeper structures of the limb, using three different pieces of calico soaked with the acid, and leaving the last in the wound as a plug to check the very free haemorrhage, which the treatment had considerably increased. He then applied several layers of calico steeped in carbolic acid and smeared with blood, so as to make a pretty thick crust overlapping the skin by about half an inch, and adapted to the crust a cap of block-tin of slightly larger dimensions, pressing it down upon the skin by means of a looped bandage encircling the leg. Having next corrected the displacement of the fragments, he moulded a pasteboard splint to the outer side of the leg and foot, strengthening it with a temporary Gooch's splint, and laid the limb on its outer side upon a pillow with the knee bent. The patient now stated that the pain he had suffered was greatly relieved. His pulse was 100. Two hours later, as a good deal of oozing of blood was still going on, a folded cloth was placed upon the tin cap and pressed down upon it with a bandage. The limb meanwhile was considerably more swollen, from bleeding into its interior, kept up, no doubt, by the sudden jerking movements which in his unreasoning condition he could not be prevented from making. The pressure employed greatly diminished the external haemorrhage, but did not entirely arrest it ; and when two hours more had elapsed Mr. Cameron

asked my advice. I recommended the use of a well-fitting internal splint, to procure greater steadiness of the fragments, and so get rid of the irritation which perpetuated the bleeding. Mr. Cameron, however, on removing the compress, found that all tendency to oozing of blood had ceased. The patient was now sober, but continued very restless. The internal splint was therefore applied, and thirty drops of solution of muriate of morphia were administered.

During the night he suffered a good deal, and got no sleep at all. Next morning, however, he complained rather of a general sense of weariness and sickness, the consequences of his debauch, than of pain; the pulse had fallen to 76; and he took his breakfast pretty well. The surface of the crust was touched with carbolic acid, and this was repeated in the afternoon, when a hot fomentation was applied to the inner side of the leg, and over this a sheet of stout block-tin, to serve, as in some previous cases, the double purpose of ensuring the efficiency of the fomentations, and acting as an internal splint. The limb was now quite easy. At night the pulse was still 76. He had made a pretty hearty supper, and felt only occasional twinges in the limb. The fomentation was changed, and the crust again touched with carbolic acid, and the opiate repeated.

He passed the following night like the preceding, without getting any sleep whatever; and in the morning his pulse was 90, although the limb was free from pain or inflammatory blush, and he made a hearty breakfast. Fearing the approach of traumatic delirium, I ordered a larger opiate to be given at night. Fifty drops of the morphia solution were accordingly administered; and after this dose he slept for about five hours. Nevertheless, he grew more restless, and was found in the morning with the leg fully extended and resting on the calf instead of on its outer side. His pulse continued at 90; and although the state of the limb and his appetite were all that could be wished, he exhibited in the afternoon unmistakable signs of delirium tremens, jerking out his tongue when asked to show it, twitching his hands in an excited manner, and declaring that his bedclothes were creeping away from him, while the restless movements of the limb were continued. I ordered a dose of castor oil, to be followed, as soon as it should have operated, by a drachm of the solution of muriate of morphia, to be repeated if necessary. He took the opiate about eight o'clock p.m., and soon afterwards dozed a little; and at eleven his pulse had fallen to 82. After this he fell into a sound sleep, from which he did not wake till six a.m.; and from this time forth he was perfectly tranquil and rational.

It is needless to enter into particulars regarding his subsequent progress further than to say that it has been in all respects satisfactory; and on the tenth day after the accident, when I saw him last, his pulse was 76, his

appetite excellent, and he had the appearance of a man in perfect health. The limb was still free from pain, while the swelling due to extravasation of blood had disappeared, and the skin was of natural aspect. After the second day from the accident, there had not been even any discharge of serum from beneath the crust, which had been daily touched with carbolic acid, the fomentations being also continued, as he found them comfortable.

I need not hesitate to say that all danger in this case is over ; and that the compound fracture is already converted into a simple one under circumstances which, even for a simple fracture, would have been trying.

In revising the proof, after nine days more have elapsed, I may add that all has continued to go on well.

PRELIMINARY NOTICE ON ABSCESS

I will now give a description of a new method of treating abscess, which has afforded results so satisfactory that it does not seem right to withhold it longer from the profession generally.

It is based, like the treatment of compound fracture, on the antiseptic principle, and the material employed is essentially the same—namely, carbolic acid, but differently applied in accordance with the difference of the circumstances. In compound fracture there is an irregular wound, which has probably been exposed to the air for hours before it is seen by the surgeon, and may therefore contain in its interstices the atmospheric germs which are the causes of decomposition, and these must be destroyed by the energetic application of the antiseptic agent. In an unopened abscess, on the other hand, as a general rule, no septic organisms are present, so that it is not necessary to introduce the carbolic acid into the interior. Here the essential object is to guard against the introduction of living particles from without, at the same time that a free exit is afforded for the constant discharge of the contents. The mode in which this is accomplished is as follows :—

A solution of one part of crystallized carbolic acid in four parts of boiled linseed oil having been prepared, a piece of rag from four to six inches square is dipped in the oily mixture, and laid upon the skin where the incision is to be made. The lower edge of the rag being then raised, while the upper edge is kept from slipping by an assistant, a common scalpel or bistoury dipped in the oil is plunged into the cavity of the abscess, and an opening about three-quarters of an inch in length is made, and the instant the knife is withdrawn the rag is dropped upon the skin as an antiseptic curtain, beneath which the

pus flows out into a vessel placed to receive it. The cavity of the abscess is firmly pressed, so as to force out all existing pus as nearly as may be (the old fear of doing mischief by rough treatment of the pyogenic membrane being quite ill-founded) ; and if there be much oozing of blood, or if there be a considerable thickness of parts between the abscess and the surface, a piece of lint dipped in the antiseptic oil is introduced into the incision to check bleeding and prevent primary adhesion, which is otherwise very apt to occur. The introduction of the lint is effected as rapidly as may be, and under the protection of the antiseptic rag. Thus the evacuation of the original contents is accomplished with perfect security against the introduction of living germs. This, however, would be of no avail unless an antiseptic dressing could be applied that would effectually prevent the decomposition of the stream of pus constantly flowing out beneath it. After numerous disappointments, I have succeeded with the following, which may be relied upon as absolutely trustworthy. About six teaspoonfuls of the above-mentioned solution of carbolic acid in linseed oil are mixed up with common whitening (carbonate of lime) to the consistence of a firm paste, which is in fact glazier's putty with the addition of a little carbolic acid. This is spread upon a piece of sheet block-tin about six inches square ; or common tinfoil will answer equally well if strengthened with adhesive plaster to prevent it from tearing, and in some situations it is preferable, from its adapting itself more readily to the shape of the part affected. The putty forms a layer about a quarter of an inch thick ; it may be spread with a table-knife, or pressed out with the hand, a towel being temporarily interposed to prevent the putty from sticking to the hand or soiling the coat-sleeve. The tin thus spread with putty is placed upon the skin so that the middle of it corresponds to the position of the incision, the antiseptic rag used in opening the abscess being removed the instant before. The tin is then fixed securely by adhesive plaster, the lowest edge being left free for the escape of the discharge into a folded towel placed over it and secured by a bandage. This dressing has the following advantages : The tin prevents the evaporation of the carbolic acid, which escapes readily through any organic tissue such as oiled silk or gutta-percha. The putty contains the carbolic acid just sufficiently diluted to prevent its excoriating the skin, while its substance serves as a reservoir of the acid during the intervals between the dressings. Its oily nature and tenacity prevent it from being washed away by the discharge, which all oozes out beneath it as fast as it escapes from the incision ; while the extent of the surface of the putty renders it securely antiseptic. Lastly, the putty is a cleanly application, and gives the surgeon very little trouble ; a supply being daily made by some convalescent in a hospital, or in private practice

by the nurse or a friend of the patient; or a larger quantity may be made at once, and kept in a tin canister. The dressing is changed, as a general rule, once in twenty-four hours; but if the abscess be a very large one, it is prudent to see the patient twelve hours after it has been opened, when, if the towel should be much stained with discharge, the dressing should be changed, to avoid subjecting its antiseptic virtues to too severe a test. But after the first twenty-four hours, a single daily dressing is sufficient. The changing of the dressing must be methodically done, as follows: A second similar piece of tin having been spread with the putty, a piece of rag is dipped in the oily solution, and placed on the incision the moment the first tin is removed. This guards against the possibility of mischief occurring during the cleansing of the skin with a dry cloth and pressing out any discharge which may exist in the cavity. If a plug of lint was introduced when the abscess was opened, it is removed under cover of the antiseptic rag, which is taken off at the moment when the new tin is to be applied. The same process is continued daily till the sinus closes.

The results of this treatment are such as correct pathological knowledge might have enabled us to predict. The pyogenic membrane has no innate disposition to form pus, but does so only because it is subjected to some preternatural stimulus. In an ordinary abscess, whether acute or chronic, the original cause that led to suppuration is no longer in operation, and the stimulus that determines the continued pus-formation is derived from the presence of the pus pent up in the interior. When an abscess is opened in the ordinary way this cause of stimulation is removed, but in its place is substituted the potent stimulus of decomposition. If, however, the abscess be opened antiseptically, the pyogenic membrane, freed from the operation of the previous stimulus without the substitution of a new one, ought, according to theory, to cease to suppurate, while the patient should be relieved from any local or general disturbance caused by the abscess, without the risk of irritative fever or hectic.

Such, accordingly, is the fact. Abscesses of large size have, after the original contents have been evacuated, furnished no further pus whatever, the discharge being merely serum, which in a few days has amounted only to a few drops in the twenty-four hours. Whether the opening be dependent or not is a matter of perfect indifference, the small amount of unirritating fluid being all evacuated spontaneously by the rapidly contracting pyogenic membrane. At the same time, we reckon with perfect certainty on the absence of all constitutional disturbance.

As an illustration, I may mention the last case which has come under my care. It is that of a young woman, twenty-five years old, with psoas abscess,

which had of late been rapidly on the increase, and caused a large swelling below Poupart's ligament, communicating with a fluctuating mass, dull on percussion, reaching to a considerable distance up the abdomen, the femoral vessels being raised over the communication between them. Six days ago I opened, in the manner above described, the swelling in the thigh at the anterior part of the limb where it was nearest the surface, giving exit to twenty-seven ounces of pus, thin, but containing numerous large curdy masses. I introduced a piece of lint, dipped in the carbolic acid and oil, into the incision ; and this prevented any discharge from escaping during the next twenty-four hours, when, on removal of the plug of lint under an antiseptic rag, three ounces of turbid serum escaped. For the next three days there was scarcely any discharge, the deeper parts of the incision having cohered. On firm pressure, however, the product of seventy-two hours escaped, and amounted to four drachms of serum. Meanwhile the girl's general health, which had not been interfered with by the abscess, continued perfectly good, neither pulse, tongue, appetite, nor sleep having been disturbed.

In this case, though there is no deformity of the spine, there is great probability that caries of the vertebrae is present. But even though such be the case, there is good reason to hope for a favourable issue. Regarding caries as merely the suppurative stage of chronic inflammation in a weak form of tissue, I have been not surprised, though greatly rejoiced, to find that it exhibits the tendency of inflammatory affections generally—viz. a disposition to spontaneous cure on the withdrawal of irritation. Hitherto, in surgical practice, caries has had to contend against the formidable irritation of decomposing matter, which, under circumstances of weakness, is often sufficient to cause ulceration, even in the soft parts ; yet, in spite of this irritation, caries is often recoverable in the child where the vital powers of all the tissues are stronger. If, therefore, this serious complication can be avoided, there seems nothing in theory against the probability that caries may prove curable in the adult. And even should portions of necrosed bone be present, as is not infrequently the case, our experience of the treatment of compound fracture with carbolic acid has taught us that dead bone, if undecomposed, not only fails to induce suppuration in its vicinity, but is liable to absorption by the granulations around it.[1]

Such were the hopes which I ventured to express several months ago to my winter class. Since that time I have opened numerous abscesses connected with caries of the vertebrae, the hip, knee, ankle, and elbow, and in all cases I have found the discharge become in a few days trifling in amount, and in many it has ceased to be puriform after the first twenty-four hours. Finally,

[1] See p. 16 of this volume.

three days ago—viz. on the 4th inst. (July 1867)—I had the inexpressible happiness of finding the sinus soundly closed in a middle-aged man, in whom I opened in February last a psoas abscess, proved to be connected with diseased bone by the discharge, on one occasion, of an osseous spiculum. For months past we had persevered with the antiseptic dressing, although the discharge did not amount to more than a drop or two of serum in the twenty-four hours, well knowing by bitter experience that so long as a sinus existed the occurrence of decomposition might produce the most disastrous consequences; and at length our patience has been crowned with success.

Hence I no longer feel any hesitation in recommending the early opening of such abscesses, because, while they remain unopened, the disease of the bone is necessarily progressive, whereas when opened antiseptically, there is good ground to hope for their steady, though tedious, recovery.

The putty of the strength above recommended, though it generally fails to excoriate the skin, sometimes produces this effect when long continued. In such case it may be reduced in strength so that the oil contains only one part to five or six without disadvantage when the discharge is very small in amount.

The application prevents the occurrence of cicatrization in the little sore caused by the incision, and perpetuates a trifling discharge from it. Hence it is impossible to judge whether or not the sinus has closed, except by examining it from time to time with a probe, which should be dipped in the antiseptic oil, and passed in between folds of the antiseptic rag. This may seem a refinement, but if we could see with the naked eye a few only of the septic organisms that people every cubic inch of the atmosphere of a hospital ward, we should rather wonder that the antiseptic treatment is ever successful than omit any precautions in conducting it.

The putty used in treating abscesses has proved very valuable in simplifying the treatment of compound fracture, and enlarging the range of its applicability, and also in dealing with incised wounds on the antiseptic principle. But I must defer a notice of these matters to a future occasion.

ON THE ANTISEPTIC PRINCIPLE IN THE PRACTICE OF SURGERY

A paper read before the British Medical Association in Dublin on August 9, 1867.

[*British Medical Journal*, 1867, vol. ii, p. 246.]

In the course of an extended investigation into the nature of inflammation, and the healthy and morbid conditions of the blood in relation to it, I arrived, several years ago, at the conclusion that the essential cause of suppuration in wounds is decomposition, brought about by the influence of the atmosphere upon blood or serum retained within them, and, in the case of contused wounds, upon portions of tissue destroyed by the violence of the injury.

To prevent the occurrence of suppuration, with all its attendant risks, was an object manifestly desirable ; but till lately apparently unattainable, since it seemed hopeless to attempt to exclude the oxygen, which was universally regarded as the agent by which putrefaction was effected. But when it had been shown by the researches of Pasteur that the septic property of the atmosphere depended, not on the oxygen or any gaseous constituent, but on minute organisms suspended in it, which owed their energy to their vitality, it occurred to me that decomposition in the injured part might be avoided without excluding the air, by applying as a dressing some material capable of destroying the life of the floating particles.

Upon this principle I have based a practice of which I will now attempt to give a short account.

The material which I have employed is carbolic or phenic acid, a volatile organic compound which appears to exercise a peculiarly destructive influence upon low forms of life, and hence is the most powerful antiseptic with which we are at present acquainted.

The first class of cases to which I applied it was that of compound fractures, in which the effects of decomposition in the injured part were especially striking and pernicious. The results have been such as to establish conclusively the great principle, that *all the local inflammatory mischief and general febrile disturbance which follow severe injuries are due to the irritating and poisoning influence of decomposing blood or sloughs.* For these evils are entirely avoided by the antiseptic treatment, so that limbs which otherwise would be unhesitatingly condemned to amputation may be retained with confidence of the best results.

In conducting the treatment, the first object must be the destruction of any septic germs which may have been introduced into the wound, either at the moment of the accident or during the time which has since elapsed. This is done by introducing the acid of full strength into all accessible recesses of the wound by means of a piece of rag held in dressing-forceps and dipped in the liquid.[1] This I did not venture to do in the earlier cases; but experience has shown that the compound which carbolic acid forms with the blood, and also any portions of tissue killed by its caustic action, including even parts of the bone, are disposed of by absorption and organization, provided they are afterwards kept from decomposing. We are thus enabled to employ the antiseptic treatment efficiently at a period after the occurrence of the injury at which it would otherwise probably fail. Thus I have now under my care in the Glasgow Infirmary a boy who was admitted with compound fracture of the leg as late as eight and a half hours after the accident, in whom nevertheless all local and constitutional disturbance was avoided by means of carbolic acid, and the bones were firmly united five weeks after his admission.

The next object to be kept in view is to guard effectually against the spreading of decomposition into the wound along the stream of blood and serum which oozes out during the first few days after the accident, when the acid originally applied has been washed out, or dissipated by absorption and evaporation. This part of the treatment has been greatly improved during the last few weeks. The method which I have hitherto published[2] consisted in the application of a piece of lint dipped in the acid, overlapping the sound skin to some extent, and covered with a tin cap, which was daily raised in order to touch the surface of the lint with the antiseptic. This method certainly succeeded well with wounds of moderate size; and, indeed, I may say that in all the many cases of this kind which have been so treated by myself or my house surgeons, not a single failure has occurred. When, however, the wound is very large, the flow of blood and serum is so profuse, especially during the first twenty-four hours, that the antiseptic application cannot prevent the spread of decomposition into the interior unless it overlaps the sound skin for a very considerable distance, and this was inadmissible by the method described above, on account of the extensive sloughing of the surface of the cutis which it would involve. This difficulty has, however, been overcome by employing a paste composed of common whitening (carbonate of lime) mixed with a solution of one part of carbolic acid in four parts of boiled linseed oil, so as to form a firm putty. This

[1] The addition of a few drops of water to a considerable quantity of the crystallized acid induces it to assume permanently the liquid form.

[2] See the preceding paper in this volume.

application contains the acid in too dilute a form to excoriate the skin, which it may be made to cover to any extent that may be thought desirable, while its substance serves as a reservoir of the antiseptic material. So long as any discharge continues, the paste should be changed daily ; and, in order to prevent the chance of mischief occurring during the process, a piece of rag dipped in the solution of carbolic acid in oil is put on next the skin, and maintained there permanently, care being taken to avoid raising it along with the putty. This rag is always kept in an antiseptic condition from contact with the paste above it, and destroys any germs that may fall upon it during the short time that should alone be allowed to pass in the changing of the dressing. The putty should be in a layer about a quarter of an inch thick, and may be advantageously applied rolled out between two pieces of thin calico, which maintain it in the form of a continuous sheet, that may be wrapped in a moment round the whole circumference of a limb, if this be thought desirable, while the putty is prevented by the calico from sticking to the rag which is next the skin.[1] When all discharge has ceased, the use of the paste is discontinued, but the original rag is left adhering to the skin till healing by scabbing is supposed to be complete. I have at present in the hospital a man with severe compound fracture of both bones of the left leg, caused by direct violence, who, after the cessation of the sanious discharge under the use of the paste, without a drop of pus appearing, has been treated for the last two weeks exactly as if the fracture were a simple one. During this time the rag, adhering by means of a crust of inspissated blood collected beneath it, has continued perfectly dry, and it will be left untouched till the usual period for removing the splints in a simple fracture, when we may fairly expect to find a sound cicatrix beneath it.

We cannot, however, always calculate on so perfect a result as this. More or less pus may appear after the lapse of the first week ; and the larger the wound the more likely is this to happen. And here I would desire earnestly to enforce the necessity of persevering with the antiseptic application, in spite of the appearance of suppuration, so long as other symptoms are favourable. The surgeon is extremely apt to suppose than any suppuration is an indication that the antiseptic treatment has failed, and that poulticing or water dressing should be resorted to. But such a course would in many cases sacrifice a limb or a life. I cannot, however, expect my professional brethren to follow my advice blindly in such a matter, and therefore I feel it necessary to place before them, as shortly as I can, some pathological principles, intimately connected not

[1] In order to prevent evaporation of the acid, which passes readily through any organic tissue, such as oiled silk or gutta percha, it is well to cover the paste with a sheet of block-tin, or tinfoil strengthened with adhesive plaster. The thin sheet-lead for lining tea-chests will also answer the purpose, and may be obtained from any wholesale grocer.

only with the point we are immediately considering, but with the whole subject of this paper.

If a perfectly healthy granulating sore be well washed and covered with a plate of clean metal, such as block-tin, fitting its surface pretty accurately, and overlapping the surrounding skin an inch or so in every direction, and retained in position by adhesive plaster and a bandage, it will be found, on removing it after twenty-four or forty-eight hours, that little or nothing that can be called pus is present, merely a little transparent fluid, while at the same time there is an entire absence of the unpleasant odour invariably perceived when water dressing is changed. Here the clean metallic surface presenting no recesses, like those of porous lint, for the septic germs to develop in, the fluid exuding from the surface of the granulations has flowed away undecomposed, and the result is absence of suppuration. This simple experiment illustrates the important fact, that granulations have no inherent tendency to form pus, but do so only when subjected to a preternatural stimulus. Further, it shows that the mere contact of a foreign body does not of itself stimulate granulations to suppurate; whereas the presence of decomposing organic matter does. These truths are even more strikingly exemplified by the fact, which I have elsewhere recorded,[1] that a piece of dead bone, free from decomposition, may not only fail to induce the granulations around it to suppurate, but may actually be absorbed by them; whereas a bit of dead bone soaked with putrid pus infallibly induces suppuration in its vicinity.

Another instructive experiment is to dress a granulating sore with some of the putty above described, overlapping the sound skin extensively, when we find in the course of twenty-four hours that pus has been produced by the sore, although the application has been perfectly antiseptic; and, indeed, the larger the amount of carbolic acid in the paste the greater is the quantity of pus formed, provided we avoid such a proportion as would act as a caustic. The carbolic acid, though it prevents decomposition, induces suppuration—obviously by acting as a chemical stimulus; and we may safely infer that putrescent organic materials (which we know to be chemically acrid) operate in the same way.

In so far, then, carbolic acid and decomposing substances are alike—namely, that they induce suppuration by chemical stimulation, as distinguished from what may be termed simple inflammatory suppuration, such as that in which ordinary abscesses originate, where the pus appears to be formed in consequence of an excited action of the nerves, independently of any other stimulus. There is, however, this enormous difference between the effects of carbolic acid and

[1] See p. 16 of this volume.

those of decomposition—viz. that carbolic acid stimulates only the surface to which it is first applied, and every drop of discharge that forms weakens the stimulant by diluting it. But decomposition is a self-propagating and self-aggravating poison; and if it occurs at the surface of a severely injured limb, it will spread into all its recesses so far as any extravasated blood or shreds of dead tissue may extend, and, lying in these recesses, it will become from hour to hour more acrid till it acquires the energy of a caustic, sufficient to destroy the vitality of any tissues naturally weak from inferior vascular supply, or weakened by the injury they sustained in the accident.

Hence it is easy to understand how, when a wound is very large, the crust beneath the rag may prove here and there insufficient to protect the raw surface from the stimulating influence of the carbolic acid in the putty, and the result will be, first, the conversion of the tissues so acted on into granulations, and subsequently the formation of more or less pus. This, however, will be merely superficial, and will not interfere with the absorption and organization of extravasated blood or dead tissues in the interior; but, on the other hand, should decomposition set in before the internal parts have become securely consolidated, the most disastrous results may ensue.

I left behind me in Glasgow a boy, thirteen years of age, who between three and four weeks previously met with a most severe injury to the left arm, which he got entangled in a machine at a fair. There was a wound six inches long and three inches broad, and the skin was very extensively undermined beyond its limits, while the soft parts generally were so much lacerated that a pair of dressing-forceps introduced at the wound, and pushed directly inwards, appeared beneath the skin at the opposite aspect of the limb. From this wound several tags of muscle were hanging, and among them there was one consisting of about three inches of the triceps in almost its entire thickness; while the lower fragment of the bone, which was broken high up, was protruding four and a half inches, stripped of muscle, the skin being tucked in under it. Without the assistance of the antiseptic treatment, I should certainly have thought of nothing else but amputation at the shoulder-joint; but as the radial pulse could be felt, and the fingers had sensation, I did not hesitate to try to save the limb, and adopted the plan of treatment above described, wrapping the arm from the shoulder to below the elbow in the antiseptic application, the whole interior of the wound, together with the protruding bone, having previously been freely treated with strong carbolic acid. About the tenth day the discharge, which up to that time had been only sanious and serous, showed a slight admixture of slimy pus, and this increased till, a few days before I left, it amounted to about three drachms in twenty-four hours. But the boy continued, as he had

been after the second day, free from unfavourable symptoms, with pulse, tongue, appetite, and sleep natural, and strength increasing, while the limb remained, as it had been from the first, free from swelling, redness, or pain. I therefore persevered with the antiseptic dressing, and before I left, the discharge was already somewhat less, while the bone was becoming firm. I think it likely that in that boy's case I should have found merely a superficial sore had I taken off all the dressings at the end of three weeks, though, considering the extent of the injury, I thought it prudent to let the month expire before disturbing the rag next the skin. But I feel sure that if I had resorted to ordinary dressing when the pus first appeared, the progress of the case would have been exceedingly different.

The next class of cases to which I have applied the antiseptic treatment is that of abscesses. Here, also, the results have been extremely satisfactory, and in beautiful harmony with the pathological principles indicated above. The pyogenic membrane, like the granulations of a sore, which it resembles in nature, forms pus, not from any inherent disposition to do so, but only because it is subjected to some preternatural stimulation. In an ordinary abscess, whether acute or chronic, before it is opened, the stimulus which maintains the suppuration is derived from the presence of the pus pent up within the cavity. When a free opening is made in the ordinary way, this stimulus is got rid of; but the atmosphere gaining access to the contents, the potent stimulus of decomposition comes into operation, and pus is generated in greater abundance than before. But when the evacuation is effected on the antiseptic principle, the pyogenic membrane, freed from the influence of the former stimulus without the substitution of a new one, ceases to suppurate (like the granulations of a sore under metallic dressing), furnishing merely a trifling amount of clear serum, and, whether the opening be dependent or not, rapidly contracts and coalesces. At the same time any constitutional symptoms previously occasioned by the accumulation of the matter are got rid of without the slightest risk of the irritative fever or hectic hitherto so justly dreaded in dealing with large abscesses.

In order that the treatment may be satisfactory, the abscess must be seen before it has opened. Then, except in very rare and peculiar cases,[1] there are no septic organisms in the contents, so that it is needless to introduce carbolic acid into the interior. Indeed, such a proceeding would be objectionable, as it would stimulate the pyogenic membrane to unnecessary suppuration. All

[1] As an instance of one of these exceptional cases, I may mention that of an abscess in the vicinity of the colon, and afterwards proved by post mortem examination to have once communicated with it. Here the pus was extremely offensive when evacuated, and exhibited vibrios under the microscope.

that is necessary is to guard against the introduction of living atmospheric germs from without, at the same time that free opportunity is afforded for the escape of discharge from within.

I have so lately given elsewhere [1] a detailed account of the method by which this is effected, that it is needless for me to enter into it at present, further than to say that the means employed are the same as those described above for the superficial dressing of compound fractures—namely, a piece of rag dipped in the solution of carbolic acid in oil, to serve as an antiseptic curtain, under cover of which the abscess is evacuated by free incision ; and the antiseptic paste, to guard against decomposition occurring in the stream of pus that flows out beneath it : the dressing being changed daily till the sinus has closed.

The most remarkable results of this practice in a pathological point of view have been afforded by cases where the formation of pus depended upon disease of bone. Here the abscesses, instead of forming exceptions to the general class in the obstinacy of the suppuration, have resembled the rest in yielding in a few days only a trifling discharge ; and frequently the production of pus has ceased from the moment of the evacuation of the original contents. Hence it appears that caries, when no longer labouring, as heretofore, under the irritation of decomposing matter, ceases to be an opprobrium of surgery, and recovers like other inflammatory affections. In the publication before alluded to [2] I have mentioned the case of a middle-aged man with psoas abscess depending on diseased bone, in whom the sinus finally closed after months of patient perseverance with the antiseptic treatment. Since that article was written I have had another instance of success, equally gratifying, but differing in the circumstance that the disease and the recovery were both more rapid in their course. The patient was a blacksmith who had suffered four and a half months before I saw him from symptoms of ulceration of cartilage in the left elbow. These had latterly increased in severity, so as to deprive him entirely of his night's rest and of appetite. I found the region of the elbow greatly swollen, and on careful examination discovered a fluctuating point at the outer aspect of the articulation. I opened it on the antiseptic principle, the incision evidently penetrating to the joint, giving exit to a few drachms of pus. The medical gentleman under whose care he was (Dr. Macgregor of Glasgow) supervised the daily dressing with the carbolic-acid paste till the patient went to spend two or three weeks at the coast, when his wife was entrusted with it. Just two months after I opened the abscess he called to show me the limb, stating that the discharge had for at least two weeks been as little as it then was—a trifling moisture upon the paste, such as might be accounted for by the little sore caused

[1] See p. 32 of this volume. [2] See p. 36 of this volume.

by the incision. On applying a probe guarded with an antiseptic rag, I found that the sinus was soundly closed, while the limb was free from swelling or tenderness ; and, although he had not attempted to exercise it much, the joint could already be moved through a considerable angle. Here the antiseptic principle had effected the restoration of a joint which on any other known system of treatment must have been excised.

Ordinary contused wounds are of course amenable to the same treatment as compound fractures, which are a complicated variety of them. I will content myself with mentioning a single instance of this class of cases. In April last a volunteer was discharging a rifle, when it burst, and blew back the thumb with its metacarpal bone, so that it could be bent back as on a hinge at the trapezial joint, which had evidently been opened, while all the soft parts between the metacarpal bones of the thumb and fore-finger were torn through. I need not insist before my present audience on the ugly character of such an injury. My house surgeon, Mr. Hector Cameron, applied carbolic acid to the whole raw surface, and completed the dressing as if for compound fracture. The hand remained free from pain, redness, or swelling, and, with the exception of a shallow groove, all the wound consolidated without a drop of matter, so that if it had been a clean cut, it would have been regarded as a good example of primary union. The small granulating surface soon healed, and at present a linear cicatrix alone tells of the injury he had sustained, while his thumb has all its movements and his hand a firm grasp.

If the severest forms of contused and lacerated wounds heal thus kindly under the antiseptic treatment, it is obvious that its application to simple incised wounds must be merely a matter of detail. I have devoted a good deal of attention to this class, but I have not as yet pleased myself altogether with any of the methods I have employed. I am, however, prepared to go so far as to say that a solution of carbolic acid in twenty parts of water, while a mild and cleanly application, may be relied on for destroying any septic germs that may fall upon the wound during the performance of an operation ; and also that for preventing the subsequent introduction of others, the paste above described, applied as for compound fractures, gives excellent results. Thus I have had a case of strangulated inguinal hernia, in which it was necessary to take away half a pound of thickened omentum, heal without any deep-seated suppuration or any tenderness of the sac or any fever ; and amputations, including one immediately below the knee, have remained absolutely free from constitutional symptoms.

Further, I have found that when the antiseptic treatment is efficiently conducted, ligatures may be safely cut short and left to be disposed of by

absorption or otherwise. Should this particular branch of the subject yield all that it promises, should it turn out on further trial that when the knot is applied on the antiseptic principle, we may calculate as securely as if it were absent on the occurrence of healing without any deep-seated suppuration ; the deligation of main arteries in their continuity will be deprived of the two dangers that now attend it—namely, those of secondary haemorrhage and an unhealthy state of the wound. Further, it seems not unlikely that the present objection to tying an artery in the immediate vicinity of a large branch may be done away with ; and that even the innominate, which has lately been the subject of an ingenious experiment by one of the Dublin surgeons on account of its well-known fatality under the ligature from secondary haemorrhage, may cease to have this unhappy character, when the tissues in the vicinity of the thread, instead of becoming softened through the influence of an irritating decomposing substance, are left at liberty to consolidate firmly near an unoffending though foreign body.

It would carry me far beyond the limited time which, by the rules of the Association, is alone at my disposal, were I to enter into the various applications of the antiseptic principle in the several special departments of surgery.

There is, however, one point more that I cannot but advert to—namely, the influence of this mode of treatment upon the general healthiness of a hospital. Previously to its introduction, the two large wards in which most of my cases of accident and of operation are treated were amongst the unhealthiest in the whole surgical division of the Glasgow Royal Infirmary, in consequence, apparently, of those wards being unfavourably placed with reference to the supply of fresh air ; and I have felt ashamed, when recording the results of my practice, to have so often to allude to hospital gangrene or pyaemia. It was interesting, though melancholy, to observe that, whenever all, or nearly all, the beds contained cases with open sores, these grievous complications were pretty sure to show themselves ; so that I came to welcome simple fractures, though in themselves of little interest either for myself or the students, because their presence diminished the proportion of open sores among the patients. But since the antiseptic treatment has been brought into full operation, and wounds and abscesses no longer poison the atmosphere with putrid exhalations, my wards, though in other respects under precisely the same circumstances as before, have completely changed their character ; so that during the last nine months not a single instance of pyaemia, hospital gangrene, or erysipelas has occurred in them.

As there appears to be no doubt regarding the cause of this change, the importance of the fact can hardly be exaggerated.

ILLUSTRATIONS OF THE ANTISEPTIC SYSTEM OF TREATMENT IN SURGERY

[*Lancet*, 1867, vol. ii, p. 668.]

I

DECOMPOSITION or putrefaction has long been known to be a source of great mischief in surgery, and antiseptic applications have for several years been employed by many surgeons. But the full extent of the evil, and the paramount importance of adopting effectual measures against it, are far from being generally recognized.

It is now six years since I first publicly taught in the University of Glasgow that the occurrence of suppuration in a wound under ordinary circumstances, and its continuance on a healthy granulating sore treated with water dressing, are determined simply by the influence of decomposing organic matter. The subject has since received a large share of my attention, resulting in the system of treatment which I have been engaged for the last three years in elaborating. The benefits which attend this practice are so remarkable that I feel it incumbent upon me to do what I can to diffuse them; and with this view I propose to present to the readers of the *Lancet* a series of illustrative cases, prefacing them with a short notice of the principles which it is essential to bear in mind in order to attain success.[1]

The cases in which this treatment is most signally beneficial are divisible into three great classes—incised wounds, of whatever form; contused or lacerated wounds, including compound fractures; and abscesses, acute or chronic—a list, indeed, which comprises the greater part of surgery. In each of these groups our aim is simply to prevent the occurrence of decomposition in the part, in order that its reparatory powers may be left undisturbed by the irritating and poisoning influence of putrid materials. In pursuing this object we are guided by the 'germ theory', which supplies us with a knowledge of the nature and habits of the subtle foe we have to contend with; and without a firm belief in the truth of that theory, perplexity and blunders must be of frequent occurrence. The facts upon which it is based appear sufficiently

[1] This plan seems preferable to continuing the formal communication, of which Part I has appeared in preceding pages of this journal (pp. 1–36 of this volume) since I shall thus be left untrammelled as to the order in which the subjects are introduced, and shall be at liberty to notice from time to time any improvements that may suggest themselves in the methods of dealing with the various classes of cases.—J. L.

convincing. We know from the researches of Pasteur that the atmosphere does contain among its floating particles the spores of minute vegetations and infusoria, and in greater numbers where animal and vegetable life abound, as in crowded cities or under the shade of trees, than where the opposite conditions prevail, as in unfrequented caves or on Alpine glaciers. Also, it appears that the septic energy of the air is directly proportioned to the abundance of the minute organisms in it, and is destroyed entirely by means calculated to kill its living germs—as, for example, by exposure for a while to a temperature of 212° Fahr., or a little higher, after which it may be kept for an indefinite time in contact with putrescible substances, such as urine, milk, or blood, without producing any effect upon them. It has further been shown, and this is particularly striking, that the atmosphere is deprived of its power of producing decomposition as well as organic growth by merely passing in a very gentle stream through a narrow and tortuous tube of glass, which, while it arrests all its solid particles, cannot possibly have any effect upon its gases ; while conversely, ' air-dust ' collected by filtration rapidly gives rise simultaneously to the development of organisms and the putrefactive changes. Lastly, it seems to have been established that the character of the decomposition which occurs in a given fermentable substance is determined by the nature of the organism that develops in it. Thus the same saccharine solution may be made to undergo either the vinous or the butyric fermentation, according as the yeast plant or another organism, described by Pasteur, is introduced into it.[1] Hence we cannot, I think, refuse to believe that the living beings invariably associated with the various fermentative and putrefactive changes are indeed their causes. And it is peculiarly in harmony with the extraordinary powers of self-diffusion and penetration exhibited by putrefaction that the chief agents in this process appear to be ' vibrios ' endowed with the faculty of locomotion, so that they are able to make their way speedily along a layer of fluid such as serum or pus.[2]

Admitting, then, the truth of the germ theory, and proceeding in accordance with it, we must, when dealing with any case, destroy in the first instance once for all any septic organisms which may exist within the part concerned ; and after this has been done, our efforts must be directed to the prevention of the entrance of others into it. And provided that these indications are really fulfilled, the less the antiseptic agent comes in contact with the living

[1] See Pasteur's papers in the *Comptes Rendus*, vols. l, li, lii, lvi, also a report by Milne Edwards on experiments performed by Pasteur before a committee of the French Academy ; *Annales des Sciences Naturelles*, March and April 1865.

[2] I have seen vibrios, so minute as to be only just discernible with the highest power of an excellent microscope, shoot across the field of view with a velocity that astonished me.

tissues the better, so that unnecessary disturbance from its irritating properties may be avoided.

The simplest conditions are presented by an unopened abscess. Here, as no septic particles are present in the contents, it is needless to apply the antiseptic directly to the part affected. All that is requisite is to guard securely against the possibility of the penetration of living germs from without, at the same time that free escape is afforded for the discharge from within. When this is done we witness an example of the unaided curative powers of Nature as beautiful as it is, I believe, entirely new. The pyogenic membrane, freed from the operation of the stimulus derived from the presence of the pus pent up within it, without the substitution of the powerful stimulus of decomposition as has heretofore been the case after the opening of abscesses, ceases at once to develop pus-corpuscles, and, exuding merely a little clear serum, rapidly contracts and coalesces, discharging meanwhile its unirritating contents completely, whether the outlet be dependent in position or otherwise. At the same time the irritative fever and hectic hitherto so much dreaded in large abscesses are, with perfect security, entirely avoided.

In suppurations of the vertebrae or of the joints the results of this system are such as I ventured with trembling hope to anticipate ; patient perseverance being rewarded by a spontaneous cure in cases where excision, amputation, or death must have resulted from any other known system of treatment. In short, the element of incurability has been eliminated from caries.

In compound fractures and other severe contused wounds the antiseptic agent must in the first instance be applied freely and energetically to the injured parts themselves, the conditions being the opposite of those in unopened abscesses. The wound being of complicated form, with its interstices loaded with extravasated blood, into which septic organisms may have already insinuated themselves during the time that has elapsed before the patient is seen by the surgeon, mere guarding of the external orifice, however effectually, is not sufficient. After squeezing out as much as possible of the effused blood, a material calculated to kill the septic particles must be introduced into the recesses of the wound ; and if the substance employed is of sufficient strength to operate to a certain extent as a caustic, this is regarded as a matter of little moment in comparison with the terrible evil of inefficiency in its antiseptic action. For experience has abundantly shown that parts killed in this way, including even portions of bone, become disposed of by absorption and organization, provided that the subsequent part of the treatment is properly managed.

Sloughs, as ordinarily observed, are soaked with the acrid products of

decomposition, and therefore produce disturbance upon the tissues around them, leading first to their gradual transformation into the rudimentary structure which, when met with at the surface of a sore, is termed 'granulations', and afterwards to the formation of pus by the granulations. But a dead portion of tissue, if not altered by adventitious circumstances, is in its proper substance perfectly bland and unirritating, and causes no more disorder in its neighbourhood than a bullet or a piece of glass, which may remain imbedded in the living body for an indefinite period without inducing the formation of pus ; while the dead tissue differs from the foreign bodies alluded to in the circumstance that the materials of which it is composed are susceptible of absorption.

Antiseptic substances, being, like the products of decomposition, chemically stimulating, will, like them, induce granulation and suppuration in tissues exposed for a sufficient length of time to their influence ; but there is this all-important difference, that an antiseptic merely stimulates the surface to which it is applied, becoming diluted and weakened by the discharge which it excites ; but the acrid salts which result from putrefaction are perpetually multiplied and intensified by self-propagating ferments, so that every drop of serum or pus effused through their agency becomes a drop of poison, extending its baleful influence both in the injured part and in the system generally.

These pathological considerations indicate the after-treatment in compound fracture, and explain the progress of the case. The antiseptic introduced into the wound is soon washed out by the discharge or carried away by the circulation, so that the blood and sloughs at first imbued with it become unstimulating and amenable to absorption, while at the same time they are prone to decomposition should any living atmospheric germs gain access to them. The further treatment, therefore, must consist in maintaining an efficient antiseptic guard over the orifice of the wound until sufficient time has elapsed to ensure complete consolidation of the injured parts.

The sanious and serous discharge which occurs at the outset will give place in a few days to a small amount of pus, if the wound is dressed in such a way that the antiseptic continues to act upon the raw surface. This discharge, due to the stimulating nature of the application, being merely superficial, and involving no inflammatory or febrile disturbance, will occasion no anxiety to one who understands its cause ; and I venture to repeat the caution given in a previous communication,[1] that the surgeon must on no account be induced to explore the wound and pry into the source of the suppuration, so long as all is going on well otherwise ; for such a course, by admitting germs into the interior, may produce the most disastrous consequences in an otherwise promising case.

[1] See p. 39 of this volume.

But although suppuration resulting from the stimulating influence of the antiseptic is no cause for anxiety, it is more convenient that it should be avoided; and this may often be done entirely by leaving the lower layers of the dressing permanently on the limb and changing only its superficial parts—a plan which, while it protects the wound against the introduction of mischievous particles, permits the foreign body in contact with the tissues to part with its antiseptic material and become an unstimulating crust, under which complete healing by scabbing may occur in wounds of a size hitherto regarded as inconsistent with this process in the human subject.

Upon these principles a really trustworthy treatment for compound fractures and other severe contused wounds has been established for the first time, so far as I am aware, in the history of surgery. In a hospital which receives an unusually large number of patients suffering from machinery accidents, and in wards which, from circumstances to which I need not here allude, were peculiarly unhealthy, my experience of compound fracture in the lower limb was formerly far indeed from satisfactory, even in the selected cases in which alone I attempted to save the limb. But since the antiseptic principle has guided us, not only have ordinary cases of this formidable injury been treated by my successive house surgeons with unvarying success, but limbs such as I should once have condemned without hesitation have gone on to complete recovery without either local or constitutional disturbance: a statement which might be suspected of exaggeration were it not that it refers to proceedings in a public hospital, witnessed not only by students, but by gentlemen once my pupils, and now practitioners in Glasgow.

In the next article I propose, after a few words regarding the principles applicable to simple incised wounds, to describe in detail the methods of procedure, illustrated by cases.

AN ADDRESS ON THE ANTISEPTIC SYSTEM OF TREATMENT IN SURGERY[1]

Delivered before the Medico-Chirurgical Society of Glasgow.

[*British Medical Journal*, 1868, vol. ii, pp. 53, 101, 461, 515 ; 1869, vol. i, p. 301.]

Mr. President and Gentlemen.—In order that the antiseptic system of treatment may confer upon mankind all the benefits of which it is capable, three things appear to be indispensably requisite. First, that every surgeon should be convinced of the reality and greatness of those benefits, so that he may be induced to devote to the antiseptic dressing of a case the same kind of thought and pains as he now, if at all worthy of the name of surgeon, bestows upon the planning and execution of an operation ; secondly, that these efforts on his part should be directed on sound principles ; and thirdly, that, for carrying out these principles, he should have thoroughly trustworthy practical means at his disposal. I venture to hope that the illustrations which I propose to bring before you this evening may promote in some degree each of these essentials.

In speaking of the antiseptic system of treatment, I refer to the systematic employment of some antiseptic substance, so as entirely to prevent the occurrence of putrefaction in the part concerned, as distinguished from the mere use of such an agent as a dressing. The latter has long been practised in many parts of the world. The former originated rather more than three years ago in this city (Glasgow). The material which I have generally used for the purpose is carbolic (or phenic) acid, which, when I first published on the subject, was new to most British surgeons as an external therapeutic agent. This circumstance, while it had the effect of attracting greater notice to the matter than might otherwise have been the case, was perhaps on the whole a misfortune, since it tended to distract attention from the essential principles of the treatment which I advocated, and to lead many in this country to look upon carbolic acid in the light of a specific. On the other hand, continental surgeons visiting our infirmary, familiar with the use of carbolic acid as an ordinary antiseptic dressing, have invariably formed a just estimate of the advantages derived from its employment upon the system to which I have alluded.

[1] This address does not profess to give a complete account of the antiseptic system, but was based upon some illustrations which happened to be at my disposal. One of these, an experiment in support of the germ theory of putrefaction, was dwelt upon at considerable length, in accordance with what I believe to be the great practical importance of the subject to which it refers.

So far from carbolic acid being a specific, it owes its virtues to properties which it possesses in common with various other substances ; and results similar in kind to those obtained by its means might be got by disinfectants long familiar to British surgery, provided always that the same principles guided their employment. This statement is not made on theoretical grounds alone. About nine months after I had first treated compound fracture with carbolic acid, Mr. Campbell De Morgan published a paper ' On the Use of Chloride of Zinc in Surgical Operations and Injuries ', and was kind enough to send me a copy of it. By means of this salt he had obtained highly satisfactory results, though led to employ it with a very different object in view. Mr. De Morgan used chloride of zinc in the first instance in cases of cancer, upon the idea that the frequency of return of the disease after operation might depend on the dissemination of its germs on the cut surface, and he hoped that, by applying a strong solution of the chloride to the wound so as to destroy any cancer-germs that might be scattered over it, he might diminish the chance of recurrence. Having treated cases of cancer in this way, he found that the wounds healed unusually kindly, while there was, at the same time, an absence of ' animal odour ', and he expressed his surprise at the small amount of ' action ' in the part. To myself it appeared perfectly natural that, if chloride of zinc prevented animal odour, implying that putrefaction was avoided, the wound, protected from the irritating influence of the products of decomposition, should exhibit little inflammatory disturbance. But it struck me as very remarkable that a single application of chloride of zinc to the raw surface should have the effect of preventing all odour of putrefaction for days afterwards ; for I knew that in the case of carbolic acid a renewal of the antiseptic to the exterior was essential in order to prevent decomposition. Hence it appeared likely that chloride of zinc would answer better for my purpose than carbolic acid, and I determined, on the first suitable occasion, to give it a trial. It was not long before an opportunity presented itself.

Case of Compound Fracture Treated with Chloride of Zinc.—A labourer was admitted into the infirmary with compound depressed fracture of the *os frontis*, caused by violent impact of the handle of a winch. I applied chloride-of-zinc solution thoroughly to the interior of the wound, and, with the view of preventing the spreading of decomposition inwards, adapted to the forehead a plate of clean block-tin overlapping the sound skin for a considerable distance, a means which, as I had before ascertained, prevents the occurrence of putrefaction in the discharge from a healthy granulating sore. The tin plate was kept in position by a piece of strapping, and over all was laid a damp folded rag to absorb discharge, with directions that it should be frequently changed. The

tin was not disturbed till about a week had expired, the patient meanwhile remaining free from any unfavourable symptoms, and not a drop of pus appearing. On removing the plate of metal, I found that the wound, instead of being hollow as when I had last seen it, was on a level with the surface of the forehead, being occupied by a chocolate-coloured mass which I supposed to be a clot, altered by the action of chloride of zinc. But when I scraped the surface of this material it bled, showing that it was in reality alive and vascular. This exactly corresponded to the most striking and peculiar of the results I had seen to follow the use of carbolic acid in compound fracture,[1] and the most likely to be mistaken for the effect of a specific action of that substance, viz. that the blood acted on by the antiseptic, though greatly altered by that action, remained susceptible of organization. Or, speaking more strictly, the product of the action of chloride of zinc upon the blood, like that of the operation of carbolic acid upon it, so soon as the irritating antiseptic material with which it was at first imbued had been withdrawn from it by diffusion into the surrounding circulation, proved a suitable pabulum for the growing elements of living tissue in the vicinity, which accordingly absorbed and appropriated it.

In the case just related, nothing could be more satisfactory than the effects of chloride of zinc. Subsequent trials, however, proved it to be very inferior to carbolic acid except in one class of cases, those, viz., in which, from the circumstances of the part concerned, it is impossible to maintain an efficient external antiseptic dressing, so that the application must be made once for all at the time of the operation. Here the permanence of the effects of chloride of zinc renders it highly valuable, as, for example, after the removal of portions of the maxillary bones. Every surgeon is familiar with the highly offensive character of the discharge for the first few days after such operations ; and there can be no doubt that the fetid state of the wound, besides being a great inconvenience to the patient and his attendants, involves a certain amount of danger. By means of chloride of zinc this complication is nearly, if not entirely avoided. In the first case of this kind in which I used it, I had to remove a considerable portion of both superior maxillary bones, on account of epithelial cancer which had spread to them from the face. I applied the chloride-of-zinc solution freely to the raw surfaces at the time of the operation, and afterwards examined the breath daily, when the only smell perceptible from first to last was an occasional odour of tobacco. [Since this address was delivered, I have used chloride of zinc with great advantage after the removal of the tongue by Mr. Syme's method, in a case of epithelial cancer.]

But in ordinary cases carbolic acid is very superior to chloride of zinc,

[1] See p. 8 of this volume.

and, so far as I am able to judge, to any other antiseptic agent with which we are at present acquainted. It presents, indeed, a remarkable combination of advantages. In the first place, it possesses the essential requisite of being a most potent poison for the low forms of life which determine putrefaction, and it retains this power even though diluted to such a degree as to be almost entirely unirritating to the tissues of the human body. In the second place, it is volatile, and its vapour is quite efficacious as an antiseptic. This gives it a great advantage over chloride of zinc or any other non-volatile substance, enabling the dressings impregnated with the acid to exert their influence not only upon objects in actual contact with them, but also upon the air in their vicinity. Again, carbolic acid is a local anaesthetic, and exercises a most soothing influence upon a painful wound. Lastly, carbolic acid is soluble in a variety of liquids of very different properties, so different, for example, as water and the fixed oils; and each of these solutions has its own special value in practice, a point to which I shall have occasion to allude further on in this communication.

And now, before speaking of some cases treated with carbolic acid on the antiseptic system, I wish to direct your attention to an experiment illustrating the germ theory of putrefaction. It is on this theory that the antiseptic system of treatment is based; and I venture to say that, without a belief in the truth of that theory, no man can be thoroughly successful in the treatment. If any one believe that putrefaction, through atmospheric influence, is due to the operation of the atmospheric gases alone upon the putrescible materials, he will be perpetually meeting with the most perplexing anomalies, and will be liable to commit the most serious practical blunders; the truth being that, on the one hand, the complete exclusion of the gases of the air affords no security against the occurrence of putrefaction, and that, on the other hand, the freest admixture of air with the putrescible contents of a wound or abscess will fail to induce putrefactive changes, if the germs of that air have been removed by filtration or deprived of vitality by a germ-poison. Of this I might, if time permitted, give several very striking illustrations from practical surgery.

The experiment which I wish to bring under your notice is a modification of one described by Pasteur,[1] not, indeed, as originated by himself, but by M. Chevreul. It is so simple, and, at the same time, so conclusive, that it should, I think, if believed, carry conviction to the minds of all. To myself the statement of Pasteur, confirmed as it is by the report of the Commission of the French Academy, before whom this, as well as various others of his experiments was performed, was perfectly satisfactory. But there was one reason that made me anxious to repeat the experiment as bearing upon the antiseptic

[1] *Comptes Rendus*, vol. l, p. 306.

system of treatment ; and this was that, so far as I read Pasteur's papers, he had performed it only with reference to the fermentation of a saccharine solution, and I wished to make sure that it applied equally to putrefaction. The experiment was performed in the following manner.

Experiment in support of the Germ Theory of Putrefaction.

On the 26th of October, just half a year ago, I introduced portions of the same specimen of fresh urine into four flasks, of which these are two. [The flasks, which were capable of containing about six fluid ounces each, were about one-third filled.] After washing the urine from their necks, which were then wide and straight, I drew out the necks by means of a spirit-lamp into tubes about a line in diameter, and in three of the flasks bent these elongated and attenuated necks at various acute angles, as you will see in one of the two before you. In the remaining flask, the neck was cut short and left vertical in position as you see it here, but its orifice was reduced to even smaller calibre than in the others. Each flask was then boiled over the lamp, and the fluid maintained in a state of ebullition for five minutes, the steam issuing freely from the orifice. The lamp was then withdrawn, and atmospheric air was permitted to rush into the flask to supply the place of the condensed steam. The flasks were then left undisturbed in the same room, the ends of their necks being still open so as to permit free exit and entrance of air as a consequence of the diurnal changes of temperature which, of course, involved alternate expansions and condensations of the contained gases. Sometimes on a cold night I have raised the temperature of the apartment considerably, and then putting the fire out, have thrown open the windows so as to occasion a depression of temperature of twenty degrees, involving the entrance of about a cubic inch of fresh air into the body of each flask. But, independently of any such exceptional treatment, a perpetual daily interchange took place between the air inside the flasks and that of the room in which they stood. And what has been the result of the action of the air upon the urine ? In the flask with straight and short, though narrow neck, I observed after ten days a minute filamentous object at the bottom of the glass. It grew larger from day to day, and was evidently a kind of minute vegetation ; and on applying a pocket magnifier, it was seen to consist of delicate branching threads. Four days after this growth first appeared, I observed an object floating on the surface of the liquid, evidently also a minute fungus ; but this in the course of a few days clearly showed itself to be of a different kind, consisting of straight radiating filaments much more closely packed, while to the naked eye its appearance was much denser than the other, which was beautifully feathery and delicate, and its colour bluish-grey instead

of perfectly colourless like the first. The two differed also remarkably in their rate of growth, that at the bottom of the vessel springing up with rapidity, so that a month after the commencement of the experiment it occupied about half the mass of the fluid, while the floating kind, though it had been steadily enlarging, had attained only about the size of a pea. Meanwhile the urine had been undergoing a change in chemical constitution, as was indicated by an alteration of its colour from a pale straw to a deep amber tint. But in the meantime, what was the condition of the urine in the three other flasks, with bent necks, of which this is a sample ? You observe it is perfectly clear and bright, free from cloud, scum, or sediment, and it retains its original straw colour, contrasting strikingly with the amber tint of the other. In short, it has precisely the same appearance as it had at the outset. I may add that, on the day after these flasks were prepared, having another similar one at my disposal, I introduced into it some fresh urine from the same source, drew out the neck and bent it into angular form, and treated it like the others, so that I have thus four flasks of boiled urine communicating with the air through bent tubes ; and in all of these the urine has remained with unchanged colour and undiminished transparency. It can hardly be doubted that this completely unaltered appearance of the fluid is associated with absence of putrefaction. I shall take an early opportunity of ascertaining whether such is the fact or not ; but in the meantime, suppose we assume that it is so. [Since the delivery of this address, namely on the 2nd inst. (May 1868), I poured out about half an ounce of urine from one of the flasks with bent neck into a wine-glass, and examined it. Its odour was perfectly sweet, and its reaction faintly acid to litmus paper, while under the microscope it showed not the slightest appearance of anything possessing vitality. I then covered the wine-glass with a piece of sheet gutta-percha to prevent evaporation, and left it at a temperature of about seventy degrees. Three days later it had already lost its brilliant transparency, and a distinct change had occurred in its odour, which had assumed something of the smell that urine has when evaporated to dryness. And under the microscope, organic forms of different kinds were present in abundance, some of them motionless delicate elongated rods (bacteria ?), others with wriggling movements, apparently of vibrionic nature, while there were also numerous amorphous and faint granules, probably also organic. Nine days after the urine had been placed in the glass, two little woolly balls of fungus were visible in it to the naked eye. In correcting the proof, I may add that the urine is now thronged with fungous growths of at least three different species ; while the odour is highly offensive. But the hot summer weather of the last two months has produced no change in the contents of either of the flasks with

bent necks.] Observe, then, what inference is to be drawn from this remarkable fact. There has been nothing in the bent tubes that could by possibility interfere with the transit of any of the gases of the atmosphere. At first, indeed, they contained some drops of condensed aqueous vapour ; but these in a few days disappeared, the tubes being dried by the air passing through them, and I beg you particularly to observe that, in the instance before you, the tube is open and dry from end to end. Every atmospheric gas, therefore, in whatever proportion it may exist, must have daily passed unchanged into the flasks to exert upon the putrescible urine any influence of which it was capable ; yet no putrefaction has occurred. The urine has remained absolutely free from putrefactive changes for half a year, though exposed during the whole of that time to the action of all the gases of the atmosphere, perpetually renewed. Surely we are safe in drawing the inference that, in the case of this putrescible substance at least, the atmospheric gases alone are incapable of inducing putrefaction. What is it, then, that is essential to putrefaction of urine by atmospheric influence which the bent tubes have arrested ? It cannot be any of the gases ; but it may be, it must be, some particles suspended in them, some dust, which the angles of the tubes might arrest mechanically. And this conclusion, inevitable as it is from the consideration of the flasks with bent necks, is confirmed by comparison with the other in which the orifice, though narrower, was purposely so arranged as to afford a better chance for the introduction of particles of dust, and in which accordingly chemical changes soon declared themselves in the contained liquid.

This experiment has an equally clear bearing upon the question of equivocal generation, essentially involved in the germ theory of putrefaction. It illustrates strikingly what appears to be the truth ; namely that even the lowest and most minute forms of life with which we are conversant, do not arise spontaneously in organic substances as the result of the operation of the atmospheric gases upon them, but take their origin from definite particles or germs, the offspring of pre-existing organisms. For, on the one hand, we have seen that this liquid, which is a most favourable nidus for such development, has remained for half a year free from any change in its appearance such as even microscopic organisms would produce, though exposed freely during that long period to the influence of air unchanged except in the circumstance that it has been filtered of suspended particles. And, on the other hand, this same liquid similarly situated in every respect, except in the fact that particles floating in the atmosphere might gain access to it, soon presented, even to the naked eye, two distinct kinds of vegetation, each springing from a definite point, and growing steadily from that point, but incapable of taking origin in any other part

of the liquid. [The facts subsequently ascertained, of the absence of any living organism which the microscope could detect in the liquid from one of the flasks with bent neck, and the speedy appearance of abundance of such minute objects as well as of others visible to the naked eye, when the liquid had been removed from its protecting chamber, afford, of course, most satisfactory confirmation.]

There is one circumstance in this experiment which may appear difficult to comprehend. Admitting that the angles of a narrow bent tube might arrest the progress of even the finest dust of air when in very gentle motion, is it conceivable that such particles could fail to be driven into the flasks during the first rush of air into them on the withdrawal of the lamp at the time of the original boiling? This difficulty is met by Pasteur in the following way. He says doubtless germs are carried in, but they pass into a liquid so hot as at once to destroy their vitality. Now, though I feel much diffidence in expressing dissent from so high an authority, I must say I do not feel satisfied with this explanation; inasmuch as Pasteur has himself related experiments which show that the mere raising of urine to the temperature of 212° Fahr. is not sufficient to ensure the destruction of the vitality of the tough-lived germs which it may contain; but that it is essential for that purpose to maintain the liquid for some minutes at the boiling-point.[1] But, if this be so, the germs introduced on the withdrawal of the lamp, being under the same circumstances as those in urine simply raised to 212° Fahr., and at once allowed to cool, should retain their vitality and give rise to organic development. The explanation which has occurred to myself is as follows. Immediately that the steam ceases to issue from the tube on the removal of the lamp, moisture is deposited upon its interior from the condensation of the aqueous vapour in it; and this moisture remains clinging to the interior of the tube, and tending to form drops at its angles, however rapidly the air be driven through it. And it seems to me natural that this water in the tube should arrest the particles in the air transmitted through it. Conversely, I am inclined to think that the germs of the two growths visible to the naked eye in the flask with straight and short neck entered with the first rush of air, but retained their vitality in the hot liquid, as in Pasteur's experiments with urine heated to 212° Fahr., and at once cooled. These two fungi had already grown to a sufficient size to be distinguishable by the naked eye, within a few days of the commencement of the experiment, but no other points of growth appeared during the ensuing month; implying that the germs of such fungi, though admitted at first, when the air entered rapidly, were excluded by the narrow though straight neck during the slow movements caused by the gradual diurnal changes of temperature.

[1] *Comptes Rendus*, vol. l, p. 306.

Believing that there must be germs of various organisms adhering to the interior of the narrow neck near its orifice, I thought that if I were to seal the orifice, and then allow some of the liquid to pass up to its immediate vicinity, I might wash down some of them into the body of the flask, and so induce other growths in the urine. Accordingly, on the 20th of November, nearly a month after the commencement of the experiment, I sealed the end of the tube with the blow-pipe, protecting the neighbouring parts of the neck from the flame as well as I could with a bit of wet lint wrapped round it. I then tilted the flask so as to cause some of the urine to pass into the neck and back again; and you will observe that there is still a drop in the immediate vicinity of the sealed extremity. A few days later, I imagined that I had attained my object, as several minute points of growth were seen upon the surface of the liquid, distinct from the original floating mass, which by this time had assumed a really beautiful appearance, its upper surface being a circle of three-quarters of an inch in diameter, composed of concentric rings of blue mould. But, in the course of a few more days, it became evident that the new growths were of identically the same species as the original floating one; and, on the other hand, that the drop near the end of the neck remained perfectly transparent, instead of exhibiting fungous developments as I had anticipated. Hence I inferred that the germs, which I could not doubt must have existed near the orifice, had been arrested so close to it as to be destroyed by the heat of the flame. Whence, then, did the new growths in the body of the flask take their origin? The answer is obvious enough. The blue mould covering the surface of the original growth teemed with myriads of sporules of the fungus, and, like larger plants, was ready to shed its ripe seeds when shaken; and the tilting of the flask, which had up to that time been carefully kept from disturbance, scattered some of these ripe germs, which grew into organisms like their parent. About a month after the sealing of the tube, all further growth of the fungi in the flask ceased, and its contents have remained unchanged for the last four months, except that the fungi have become shrunk and unhealthy in aspect. This I attribute to the cutting off of the supply of oxygen by the sealing of the tube. [This view has since been verified. On the 2nd inst. (May 1868), I broke off the sealed end of the neck after scratching it with a file, leaving the flask otherwise undisturbed. In four days, I detected the first indications of return of the growth which had been so long suspended; and, a few days later, the dwindled and discoloured original growths were abundantly covered with fresh vegetations of the same nature as before, while the surface of the fluid presented multitudes of new points of development of the same species; the unavoidable motion of the liquid in conveying the flask to and from the meeting, which

indeed greatly marred the beauty of the fungi, having evidently scattered other germs about, which remained latent till fresh air was admitted.]

Looking at this experiment as a whole, we see that the atmosphere was rendered incapable of inducing in that specimen of urine either putrefaction or the formation of even the lowest and most minute known organisms, by merely depriving it of its suspended particles; or, conversely, that the 'air-dust' is the essential cause both of organic development and of putrefactive changes in such a liquid; while the experiment further illustrates what seems to be a general law; viz. that the low forms of life to which the atmospheric particles give rise, so far as we are able to observe them, resemble higher plants or animals in springing only from pre-existing organisms. Any one who bears these facts in mind will have little difficulty in admitting the truth of the germ theory of putrefaction; and I venture to recommend to any of you who may hereafter feel perplexed by the contradictory and bewildering statements of various authors upon this subject, and be tempted to regard it as hopelessly obscure, that he should recall to his memory the clear evidence respecting it which has been brought before you this evening.

Emphysema and Pneumothorax from Simple Fracture of the Ribs.

This mode of experimenting, as described by Pasteur, besides charming me by its simplicity and conclusiveness, had a further special interest for myself, because, before knowing of it, I had explained to my own mind on the same principle the remarkable fact, previously quite inexplicable, that, in simple fracture of the ribs, if the lung be punctured by a fragment driven inwards upon it, the blood effused into the pleural cavity from the wound in the highly vascular organ, though freely mixed with air which enters the pleura through the same orifice, undergoes no decomposition, as is clearly implied by the absence of any symptoms of pleurisy in such cases. The air is sometimes pumped into the pleural cavity in such abundance that, making its way through the wound in the pleura costalis, it inflates the cellular tissue of the whole body; yet this occasions no alarm to the surgeon, unless the opening in the parietal pleura become insufficient to permit free egress for the air, which then becomes pent up in the serous cavity, and, distending it far beyond its natural dimensions, encroaches on the other lung so seriously as to embarrass or even abolish its functions. Thirteen years ago, I had the opportunity of making a post mortem examination of the body of a man who had died under such circumstances ten days after the receipt of the injury which caused his symptoms; and I was much struck to find the enormously distended pleura free from effusion, and perfectly smooth and healthy. Why air introduced into the pleura through

a wounded lung should have such totally different effects from that entering through a permanently open penetrating wound from without, was to me a complete mystery till I heard of the germ theory of putrefaction, when it at once occurred to me that, though we could not suppose the gases of the atmosphere to be in any way altered in chemical composition by passing through the trachea and bronchial tubes on their way into the pleura, it was only natural that they should be filtered of germs by the air-passages, one of whose offices it is to arrest inhaled particles of dust, and prevent them from entering the air-cells. In truth, this fact in practical surgery, when duly considered, affords as good evidence in support of the germ theory of putrefaction as any experiment that can be performed artificially.

Another remarkable example of the same thing, though brought about by different circumstances, occurred recently in my practice at the infirmary.

Case of Penetrating Wound of the Thorax and Abdomen.—On the 1st of October last, a butcher, aged 18, was admitted on account of a most serious wound of the chest, inflicted by a comrade who, angry at having a dirty bladder thrown at him by the patient, threw in return his knife, with a blade nine inches long, and keen-edged, half of which buried itself in the patient's infra-axillary region, between the ninth and tenth ribs. He himself drew out the knife, which was followed by a fearful gush of blood. Being accustomed to see blood flow, he said ' there was a spout of four inches before the fall '. He was immediately taken to the hospital, where my then house surgeon, Mr. Hector Cameron, found him blanched, his clothes drenched with blood, which was still pouring from the wound, venous in colour, and with a tendency to regurgitate during inspiration, implying that it proceeded from a wound in the lung, which was further indicated by the occurrence of haemoptysis. There was also protruding from the external wound a piece of omentum five inches long, showing that the knife had passed through the diaphragm into the abdominal cavity. No time was to be lost, as death from haemorrhage was imminent ; and Mr. Cameron judged it best to plug the wound, but at the same time to introduce an antiseptic as in compound fracture, in order to destroy any atmospheric germs that might have been drawn in during inspiration. With this object, after cutting off the protruding piece of omentum, which he kept to show me, he soaked a piece of lint with a solution of carbolic acid in four parts of boiled linseed oil, and by means of dressing-forceps passed it as far as he could in every direction in the pleural cavity, repeating the application several times. He then took two strips of lint steeped in the same solution, each about a foot long and an inch in breadth, and pushed them into the pleura, one upwards, the other downwards, as far as possible consistently with keeping their ends

protruding externally ; and, the wound being thus plugged antiseptically, he applied a sheet of paste composed of whitening mixed with the oily solution of carbolic acid before mentioned, taking care that it was large enough to overlap the skin around the orifice by several inches in every direction, retaining it in position by strapping and bandage. It may, perhaps, be said by some of you, 'Surely it was heroic practice to introduce irritating carbolic acid so freely into that important serous cavity. Would it not have been a milder and more prudent course to have plugged the wound with a piece of dry lint ?' But any one who argues in this way forgets what would have been the inevitable result of such a procedure. The mass of blood accumulated in the pleura would necessarily have been soon decomposed through the agency of the germs contained in the lint ; and the putrefying mass, growing from day to day more acrid in the cavity in which it was confined, would undoubtedly have soon caused the death of the already prostrated patient. On the other hand, carbolic acid, being a local anaesthetic, is much less irritating, even when first applied, than the products of decomposition ; and it also differs from the latter in this all-important point, that it soon becomes dissipated by diffusion and removed by the surrounding circulation, when, the blood on which it has acted being still amenable to organization and absorption, the part is as favourably situated as if affected only with a subcutaneous injury. Next day, when I saw the patient for the first time, I cautiously withdrew the plugs, under the protection of a large piece of lint dipped in the oily solution of carbolic acid, and continued the use of the paste. For about ten days the patient progressed admirably, the pulse descending, the laboured rapid respirations growing less laboured and less rapid, and altogether his condition becoming so much improved that he could not be prevented from sitting up in bed, singing songs, and conducting himself otherwise in an imprudent manner. Meanwhile, examination of the thorax disclosed signs of the presence of both blood and air in the pleura, such as dullness of the base and preternatural resonance of the upper and anterior part of that side of the chest, and metallic tinkling, which was well marked. And to such an extent had this accumulation of blood and air proceeded, that the heart had been pushed over towards the right side, so that its apex beat below the right nipple. And yet this mass of blood, freely exposed to the influence of air, had not decomposed. Any putrefactive germs introduced through the external wound had been destroyed by the carbolic acid, and the air, entering the pleura through the wounded bronchial tubes, had deposited its floating organisms upon the slimy mucous secretion of those tortuous canals. Hence the patient remained free from any symptoms of irritation, and suffered only from loss of blood and the embarrassment of the respiration which was

the mechanical result of the injury. But, thirteen days after the accident, profuse haemoptysis appeared, which I was disposed to attribute to tearing open of the wound in the lung through his imprudent exertions; and this, continuing for several days, threatened entirely to exhaust his weakened frame. The expectorated blood assumed also a putrid odour, like that from gangrene of the lungs; and I was apprehensive that the putrescence might spread to the mass in the pleura. Fortunately, however, this did not occur. The bloody expectoration gradually became purulent, and then diminished in quantity till it ceased entirely. With regard to the external wound, it furnished no pus so long as the original mode of dressing was continued. In the first twenty-four hours, there was a free discharge of bloody serum; but this grew less from day to day, till, six days after the receipt of the injury, it amounted to less than a minim in forty-eight hours; and when the piece of lint, which had been kept permanently on the wound beneath the paste, was removed, between three and four weeks after the accident, a superficial sore was found, which afterwards cicatrized kindly. On the 18th of November, seven weeks after his admission, the apex of the heart was observed to be again beating below the left mammilla; and, finally, I may add, that he was seen a few days ago by Mr. Cameron, engaged with another butcher in driving a herd of unruly cattle through the streets, when our former patient, though still pale from anaemia, proved the more vigorous of the two in turning the animals; while his lusty exclamations, though not couched in the most decorous language, gave satisfactory evidence of the soundness of his lungs.

Ligature of Arteries.

I have now to show you a preparation illustrating the effects of the application of a ligature upon an artery on the antiseptic system. The theory of such a procedure is simple. A foreign body introduced among the tissues does not exert any disturbing influence upon them, unless it be either mechanically or chemically irritating. Thus, it is well known that a needle or a spiculum of glass may lie for an indefinite period embedded in the living textures without inducing suppuration; and any irritation which may result is due simply to the rigidity and form of the foreign solid. Now, a bit of silk or linen thread being composed of materials of soft consistence and as unstimulating chemically as glass or steel, its presence among the tissues cannot of itself occasion any disturbance. But, unlike the glass or metal, the thread is porous, and contains in its interstices putrefactive germs, which, developing in the serum that bathes the ligature, give rise to the acrid products of decomposition, and these, in their turn, stimulate the surrounding tissues to granulation and suppuration. If,

however, the thread were steeped in some liquid calculated to destroy the life of the germs in its interstices, and the wound by which it was introduced were dressed antiseptically, the ends of the ligature being cut short, it might be left with confidence that its presence would not interfere with primary union, or occasion any disorder in the surrounding parts. [The traction exercised on the external coat by the noose of the ligature is no doubt a temporary cause of mechanical irritation, but this does not appear to have any considerable influence.] Before applying these principles upon the human subject, I thought it right to test them on one of the lower animals.

Ligature of the Carotid Artery in the Horse, on the Antiseptic System.—On the 12th of December last, I tied the left carotid of a horse about the middle of the neck, using fine but strong ' purse-silk ', unwaxed, but steeped for some time in a saturated watery solution of carbolic acid. [The product of the action of carbolic acid upon blood serves the purpose of wax in preventing the first half of the knot from slipping during the tying of the second half.] The ligature having been tightly tied, so as to rupture the internal and middle coats, its ends were cut short, and the wound was freely treated with carbolic acid dissolved in forty parts of water. Seven stitches of the coarse soft wire used by veterinary surgeons for the purpose were introduced into the long wound, the most dependent part being left free for the escape of discharge. The hair around the wound was well rubbed with a solution of carbolic acid in four parts of olive oil, and cloths saturated with the same antiseptic oil were applied overlapping the surrounding skin freely, and retained in position by means which I need not describe; and similar oil was poured daily upon the cloths for the first six days. Ten days after the operation I removed the dressings, and found the wound perfectly united throughout, except at the part purposely left open, which was covered with a sort of cheesy material, and as each stitch was removed there was absence of even serous exudation. The wound was now left exposed, and in three days more the lower part had healed by scabbing, no suppuration having occurred from first to last. At the same time, there was none of the swelling and induration that usually attend the application of a ligature to a vessel in the horse's neck, and the animal showed no signs of uneasiness when the part was freely handled.

Five weeks and four days after the tying of the artery, the creature, though it had improved greatly in condition under its superior diet in the veterinary establishment, died, as the groom believed, of exhaustion from struggling ineffectually to rise from the recumbent posture. I had thus an opportunity of inspecting the parts concerned in the operation, some of which are now before you. In the first place, here is a portion of the skin containing the scar; and you will observe that it is a perfectly sound linear cicatrix, barely traceable

among the hair. Here is the artery, slit up to show the condition of the interior. At the cardiac side of the place where the ligature was applied there was, as you see, an adherent coagulum, an inch and a quarter in length. But at the distal side there was no adherent clot, doubtless in consequence of the circulation through a large branch, about as big as the human vertebral, which came off, you will observe, as close to the situation of the ligature as was possible.

The cul-de-sac formed by the distal end, though it showed indications of the puckering of the divided internal and middle coats, was completely cicatrized, the smooth lining membrane of the artery being continuous over the irregular surface. Why it was that the immediate vicinity of so large a branch did not lead to secondary haemorrhage, was clear from the state of things beside the ligature, which lay embedded in a firm fibrous structure, with not only no pus, but no granulations, no softening of tissue around it. The portion of the external coat included in the noose, though doubtless killed by the violence with which it was pinched, had not been thrown off as a slough, but, being unstimulating, because undecomposing, it had been absorbed and reproduced by the living parts near it; while the thread had been bridged over externally by dense fibrous tissue, so that the vessel showed but little appearance of constriction where it had been tied, and it appears to be as strong at this part as at any other. You may form some estimate of its strength from the manner in which it resists the traction to which I now subject it. Here is the ligature with its short cut ends, apparently unchanged, except that it was divided in my search for it in its fibrous bed.

This case confirms the hope I ventured to express at the meeting of the British Medical Association in Dublin last autumn,[1] that the antiseptic system would free the deligation of a large artery in its continuity of the two essential elements of danger to which it is now liable, viz. an unhealthy condition of the wound, and secondary haemorrhage. Thus encouraged, I felt justified in carrying a similar practice into human surgery.[2]

The success of these cases of ligature depends, as we have seen, upon the circumstance that not only a neutral foreign body, but a portion of dead tissue, if simply protected from putrefaction, is entirely devoid of irritating properties. A good example of this fact is presented by a case at present under my care.

Case of Acute Necrosis treated on the Antiseptic System.—The patient is a boy, eight years of age, who was admitted into the infirmary on the 25th of January, 1868, having, five days previously, received a violent blow upon the

[1] See p. 45 of this volume.

[2] The first part of the report of the case of Ligature of the External Iliac Artery, the first of that nature to which the antiseptic system was applied, was here given, but has been omitted, being inserted at the proper place in the next paper, 'Observations on Ligature of Arteries on the Antiseptic System' (see p. 88).

left leg with a heavy pair of tongs, resulting in intense inflammation in the limb, which was red and swollen from the knee to the ankle. Fluctuation being distinctly perceptible over the upper part of the tibia, the matter was evacuated antiseptically. A piece of lint dipped in an oily solution of carbolic acid having been laid upon the part where the incision was to be made, its lower edge was raised to allow a knife smeared with the same solution to be plunged into the cavity of the abscess, when the curtain was at once dropped so that the pus might flow out beneath it. When all the matter had been pressed out, an external antiseptic dressing was applied, and this was afterwards changed daily. Four other abscesses afterwards made their appearance at intervals down the limb. These were treated in the same way ; and in every case when a probe, carefully guarded by being passed among folds of lint steeped in the antiseptic oil, was introduced into the incision, it came into contact with bare bone. This was of itself sufficient evidence that portions of the tibia, of greater or less thickness, were dead ; for, had the periosteum been raised by suppuration from living bone, the osseous surface would have become covered with granulations during the process. But evidence which must satisfy the most incredulous is afforded by the fact that, between two and three weeks after the first abscess was opened, a probe introduced into the orifice still passed down to bare bone. Under such circumstances, what, it may be asked, could be the advantage of continuing the antiseptic dressing ? If dead bone was present, whether in larger or smaller amount, must it not become detached from the living osseous tissue by a gradual process of exfoliation, which an antiseptic applied to the skin could neither promote nor hinder ? Such may be a natural inquiry. But having seen a large mass of dead bone absorbed before my eyes by the granulations that enveloped it, in a case of compound fracture treated antiseptically[1] ; and having also had evidence from post mortem examination in a case of hip-joint disease where extensive necrosis existed in connexion with caries, that bone killed by inflammation might, under antiseptic management, fail to induce suppuration ; putting those facts together, I thought it not unlikely that, in the case we are considering, the dead portions of the tibia would be absorbed by the living tissues around them, if we perseveringly maintained an effectual external antiseptic guard. Such, then, was the practice we pursued, and the result was such as I had anticipated. The various incisions successively healed, till by the 6th of April, eleven weeks after the receipt of the injury which caused the attack, the abscess last opened was soundly closed and cicatrized, not a particle of dead bone having come away from any of the openings. At the same time, the swelling of the limb, instead of increasing, as is the case under ordinary treatment, from

[1] See p. 16 of this volume.

formation of new bone in the periosteum under the stimulating influence of exfoliations soaked with putrid liquids, had disappeared almost entirely from the upper part of the leg, which was that primarily affected, and was rapidly diminishing elsewhere. [On the 18th of May, the boy left the hospital with the full use of the limb. I had intended giving him a somewhat longer rest in bed as a measure of precaution. But I found that for a considerable time it had been impossible to keep him from getting up and running about the ward ; and he was none the worse for his activity.] This certainly was very different from the tedious course of such cases under ordinary treatment.

With regard to the manner in which the dead bone has been disposed of, some who have not witnessed similar occurrences may doubt the possibility of its absorption, and believe that the necrosed pieces are still lying unchanged in the interior of that leg. But even those who take such a view must admit that we have here a most striking illustration of the important truth, that dead tissue, if protected from putrefaction, is of itself incapable of exerting any disturbing influence upon surrounding parts.

Carbolic Dressings.

I will now proceed to speak of the mode of dressing. Carbolic acid, as I have already remarked, is soluble in liquids of very different kinds, so different, for example, as water and one of the fixed oils ; and each solution has its own special value. Water, having little affinity for the acid, dissolves but a small quantity, only one-twentieth part of the pure crystals,[1] and holds that small quantity very loosely, so as to permit it to act with energy on any substance for which it has stronger attractions, and also to become soon dissipated on exposure. Hence, the watery solution is a pretty potent but transient application. Now this is exactly what we want when we apply carbolic acid to the interior of a wound for the purpose of destroying any germs which may have been introduced into it. We require something that will act with energy for the moment ; but which, as soon as it has extinguished the vitality of the septic particles, may disappear from the wound, in order that the tissues may be left free from all unnecessary irritation. The fixed oils, on the other hand, have so strong an affinity for the acid that they will mix in any proportions with it, and hold it so firmly as not to permit it to act with much energy on the tissues,

[1] The impurities often met with in carbolic acid interfere with its solubility in water. The first specimen with which I happened to experiment was an impure liquid kind, sold as ' German creosote ', and this was absolutely insoluble in water ; the associated organic compounds having, apparently, too strong an affinity for the acid to permit water to appropriate any of it. I was thus led into the mistake of stating that carbolic acid is insoluble in water (see note on p. 4 of this volume). I may remark that the public are much indebted to Mr. Crace Calvert, of Manchester, for his successful efforts to prepare carbolic acid in a pure form at a moderate price.

or to become soon dissipated into the atmosphere. Hence an oily solution is comparatively bland but permanent in its operation. These are just the properties which are desirable for an external application. We wish it to serve as a reservoir of the acid, retaining it for twenty-four hours at least, so that it may remain constantly exerting its antiseptic influence upon the discharges that flow out beneath it. At the same time it is most important that it should be mild in its action on the surface to which it is applied, in order to avoid irritation and excoriation. It appears clear, therefore, that a watery solution is best adapted for the treatment of the interior of a wound in the first instance, while an oily preparation is suited for an external dressing.

We have next to consider the best form for the oily application. I have used various forms; of which some have proved trustworthy, and others not so. One that has shown itself thoroughly reliable is a paste composed, like glazier's putty, of boiled linseed oil and whitening, but with the addition of about one part of carbolic acid to four of the oil. Even in the case of large abscesses, where there has been in the first instance a profuse discharge, the putty, if properly applied and retained securely in position, prevents with perfect certainty the spread of putrefaction into the interior. But the putty is a somewhat clumsy and inconvenient preparation, and I have been desirous, if possible, to get rid of it. Within the last few months I have given a full trial to cloths dipped in a solution of carbolic acid in olive oil, but I am sorry to say that this method, though attractive from its simplicity, is not reliable. It is true, indeed, that we have had some beautiful cases under this mode of management; as for example the following.

Case of Compound Fracture of the Right Leg and Severe Contused Wound in the Left Foot, in a Person of Advanced Age.—On the 31st of January last, a woman, aged seventy-four years, was admitted into the infirmary, having been run over by a heavily laden omnibus. The wheels had passed over both lower limbs, producing in the right leg compound fracture of both bones a little above the ankle, with a considerable wound on the outer side of the limb communicating with the broken fibula, and another on the opposite aspect, not directly connected with the seat of fracture. In the left limb the violence had been sustained by the foot, which presented at its inner aspect a large gaping contused wound, four inches long and two inches broad, while the skin was extensively detached, so that when a watery solution of carbolic acid had been introduced at the wound, pressure over the skin at the outer or opposite side caused some of the fluid to escape, showing that it had passed freely over the upper surface of the foot, beneath the undermined integument. She had also a wound on the forehead, two inches long, exposing the os frontis. From these

various injuries she had lost a great deal of blood, and she was also suffering from contusions in other parts of the body. All the wounds were dressed with layers of lint soaked with a solution of carbolic acid in olive oil ; the superficial layer, larger than the rest, being changed daily while the deeper layers were left undisturbed. Under this treatment the wound on the forehead healed without the formation of a drop of pus, and those in connexion with the compound fracture were converted into superficial granulating sores, without any more disturbance, local or constitutional, than if the fracture had been a simple one ; and the bones united in the usual period under the use of pasteboard splints. But the most remarkable circumstance in the case was the progress of the injury of the foot. Three days after the accident, my house surgeon, Mr. Appleton, observed that a considerable portion of the undermined skin on the dorsum of the foot had lost its vitality ; and instead of adopting the usual course of applying wet lint or a poultice till the slough should separate, he extended the antiseptic dressings so that they overlapped the dead portion of tissue for a considerable extent in every direction ; after which, the daily changing of the superficial layer was continued as before. The result, though in strict accordance with the principles which I am endeavouring to enforce, was strikingly opposed to ordinary experience. After the subsidence of the copious sanious effusion which took place immediately after the injury, the discharge became reduced to about one minim in twenty-four hours, without any distinct appearance of pus, while the foot remained free from the slightest uneasiness, so that she moved it as usual in the bed, and imagined it perfectly recovered. Such being the case, knowing, as I did, that to remove the deep dressings would be to induce, at the best, two large granulating sores which must, from that time forward, furnish a considerable amount of pus that would act as a drain upon the old lady's feeble system, I left the crust of lint and dried exudations untouched for seven weeks, at the end of which time it became spontaneously detached. On raising it, we found a narrow line of cicatrix along the inner side of the foot, complete healing by scabbing having occurred in, I suppose, the largest wound ever known to heal in that manner in the human subject. And on the dorsum of the foot, in place of the large slough, was a broad scar, a portion in the centre about as large as a fourpenny-piece alone remaining unhealed ; the dead tissue having, apparently, been absorbed, as none of it was found on the dressing. The superficial layer of antiseptic lint, daily renewed, had answered the purpose of preventing putrefaction from spreading inwards, while the thickness of the permanent crust had kept the carbolic acid constantly supplied externally from penetrating to its deepest parts. Hence, the portion of the dressing in contact with the skin, having lost its original acid by diffusion into the circulation,

before sufficient time had elapsed for granulation and suppuration to take place under the stimulating influence of the antiseptic, became a perfectly unirritating or neutral body, and the dead portion of tissue beneath it, being in like manner destitute of any stimulating properties, became amenable to absorption, like the bit of the external coat in the noose of the antiseptic ligature, or the dead bone in the case of necrosis, above related.

But, while I have mentioned this case as a good example of the behaviour of severe injuries under antiseptic management, I wish it to be distinctly understood that I do not recommend the mode of dressing adopted. For, as I have already stated, and as bitter experience in some other cases has but too clearly convinced me, it cannot be implicitly relied on. The reason why it is less trustworthy than the putty is sufficiently plain. The lint, being porous, absorbs the discharge, which, as it enters, displaces the antiseptic oil, and may thus, if profuse, establish a channel of putrescible materials from the external atmosphere to the wound. Again, when the discharge has passed through the dressing, even though it have been imbued with carbolic acid in its passage, it gives it off into the atmosphere on exposure, when it becomes again liable to putrefaction, and, having putrefied, may soak back into the porous dressing, and deprive it entirely of antiseptic virtue. For carbolic acid and the products of putrefaction exert a powerful chemical action upon each other ; and, on this account, the former is a deodorant as well as an antiseptic, and, conversely, the latter, if in sufficient quantity, neutralize the acid and render it inert. In this way, I have known a dressing, consisting of several layers of the oiled lint, lose all odour of carbolic acid and acquire that of decomposition within twenty-four hours of its application.[1] The putty, on the other hand, being impermeable to the discharge, retains the carbolic acid securely stored up, except in so far as it is exhaled from the surface, to maintain a constant antiseptic action upon the blood, serum, or pus that flows out beneath.

Impermeability to a watery fluid being thus evidently the essential cause of the superior efficacy of the putty, the chalk, which is its chief constituent, being of no other use than to give consistency to the mass, it naturally occurred to me that, if the oily vehicle of the carbolic acid were in a solid form, the chalk might be dispensed with, and the advantages of the putty might be obtained in a less bulky and more convenient form. I tried, in the first place, various

[1] If fresh oil is assiduously supplied at short intervals by night as well as by day, this objection to oily cloths as a dressing is removed. But this would in many cases be impracticable ; and, as a general rule, it is obviously undesirable, from the trouble and uncleanliness involved in it. There are situations, however—such as the perineum—in which this is probably the best mode of management. And it may be added that, in any case where the discharge is very trifling, oiled lint, changed once in twenty-four hours, will prove sufficiently reliable.

kinds of *emplastra* ; but these appeared objectionable on account of their adhesiveness, which is greatly increased by the admixture of carbolic acid, and which seemed likely to be mischievous by retaining the discharge. I next employed paraffin, mixed with a little wax to give it tenacity, and a little olive oil to confer the requisite softness. This certainly made, under ordinary circumstances, an effective as well as elegant substitute for the putty, being perfectly devoid of adhesiveness, while a comparatively thin layer proved securely antiseptic. But the paraffin cerate had this great disadvantage, that, in situations where it was subjected to much movement, such as the groin, it was apt to crumble down and become useless. Meanwhile I learned that Dr. Watson, of Edinburgh, was employing soap-plaster mixed with carbolic acid, and that, though adhesive, it appeared to work well ; the discharge finding its way out beneath it. Thus I was again induced to try *emplastra* ; and of late we have been using what seems to answer admirably, namely *emplastrum plumbi* mixed with one-fourth part of bees-wax to give it sufficient consistence, the carbolic acid being in the proportion of about one-tenth of the whole.[1] This is used as a plaster spread on calico in a layer of about one-twentieth of an inch thick, and I can recommend it as thoroughly reliable. There is a case which I am dressing with it at the present time, which I may mention on account of its interest otherwise.

Case of Old Fracture at the Ankle with Fixed Displacement of the Foot, Rectified

[1] In making the plaster with the ingredients mentioned in the text, the *emplastrum plumbi* and the bees-wax are melted and mixed together, and allowed to cool, till the liquid begins to thicken ; the carbolic acid is then added and stirred in, which has the effect of bringing back the mass into the state of a thin liquid, which is assiduously stirred till it thickens, to prevent the wax from separating in granules. This plaster is, however, inconveniently soft, and cannot be kept spread in stock. I have since found that by increasing the proportion of litharge, the lead soap may be made of any degree of firmness that may be desired, provided that water be not used in the manufacture. When the litharge and olive oil are in the proportions directed by the *Pharmacopoeia*, a certain quantity of water must be added to promote the combination of the fatty acids with the oxide of lead, and even then the process is a very tedious one. But it is an interesting fact chemically, that if the litharge is used in about four times the pharmacopoeial proportions, although no water be employed, the combination proceeds under a brisk heat with great rapidity. It is upon this fact that the following method of manufacture is based:

Take of olive oil, 12 parts by measure ; litharge (finely ground), 12 parts by weight ; bees-wax, 3 parts by weight ; crystallized carbolic acid, 2½ parts by weight. Heat half the oil over a slow fire ; then add the litharge gradually, stirring constantly till the mass becomes thick or a little stiff. Then add the other half of the oil, stirring as before till it becomes again thick. Then add the wax gradually till the liquid again thickens. Remove from the fire and add the acid, stirring briskly till thoroughly mixed. Cover up close and set aside, to allow all the residual litharge to settle ; then pour off the fluid, and spread upon calico to the proper thickness. The plaster made in this way can be spread by machine, and kept rolled up in stock ; and, if in a well-fitting tin canister, will retain its virtues for any length of time. This I believe to be the most perfect form in which an antiseptic lead-plaster can be obtained. For almost all purposes, however, it is superseded by the lac-plaster, which will be found described in the succeeding part of this address. These improvements in the materials for dressing have occupied a much longer time than I had anticipated ; and have been the cause of the delay in publication.—J. L.

by Aid of the Antiseptic System.—A young man, aged twenty-nine, was engaged in mooring a vessel on the 11th of December, 1867, when one of the massive ropes, used for the purpose, slipped and struck him with violence at the outer and posterior aspect of the ankle, fracturing the fibula about two inches above the joint, and breaking off the internal malleolus at its base, driving the bones of the leg forwards and inwards with respect to the foot, or, in other words, producing displacement of the foot backwards and outwards. Four months after the receipt of this injury he came under my care in the infirmary, with the heel very prominent and the foot greatly everted, and firmly fixed in its abnormal position by osseous union of the fragments. In this condition the limb was absolutely useless, and the question arose whether anything could be done to restore it. It was clear that the foot could not be replaced without breaking through the 'callus' which could be plainly felt in both bones, and there seemed no prospect of being able to do this without cutting down and adopting means which, in the case of the tibia, would necessarily involve opening into the articulation, or producing artificially a compound fracture into the ankle-joint. This I certainly should not have dreamed of doing without the aid of the antiseptic system, being well aware of the disastrous course such injuries commonly run under ordinary management. If I had operated at all, I should have made a point of removing the end of the tibia, and even then I should have felt that I was subjecting the patient to some risk. But feeling confident that I had the means of converting a compound fracture into a simple one, I did not hesitate to adopt the following procedure. On the 11th inst. (April 1868), the man being under the influence of chloroform, I made a curved incision behind and below the prominent end of the tibia; and, a solution of carbolic acid in about four parts of olive oil being dropped into the wound during the progress of the operation, I detached the soft parts from the bone sufficiently to enable me to insinuate behind the callus one blade of a pair of cutting pliers, smeared with the same oil, and then having placed pieces of lint, soaked with the oil, around the blades of the pliers, so as to prevent the chance of septic air entering the joint when the bone should give way, divided the callus, and at once covered the wound with the antiseptic lint. I then made a longitudinal incision over the seat of fracture in the fibula, and divided it with similar precautions. Having thus overcome the obstacle presented by the bones, I proceeded to draw the foot towards its proper position by pulleys acting upon its outer and posterior part through the medium of a skein of worsted passed round it, while a padded belt supported the opposite aspect of the leg above the ankle: the wounds being kept carefully covered with the oiled lint. When a considerable amount of force had been used there was a sudden sensation of

something giving way ; and now, on removing the apparatus, the foot was found to have resumed its natural place. The wounds were then dressed with layers of lint soaked with a weak oily solution of carbolic acid, and covered with the antiseptic plaster ; after which, a Dupuytren's splint was applied at the inner side of the limb to prevent eversion, and Mr. Syme's horseshoe splint anteriorly to obviate the tendency to displacement backwards. Fresh plaster has since been applied daily ; and the result has been that, while the foot has retained its position satisfactorily, the patient has not suffered at all either locally or constitutionally, during the six days that have elapsed since the operation. His pulse has remained 68 or 70, he has not lost his sleep a single night, his tongue has been quite clean, and his appetite good. In fact, he has taken his food with better relish than before, because he has been freed from his previous gloomy prospect of hopeless lameness, while the operation has caused him no anxiety ; as the assurance which I felt justified in giving him, that it was entirely free from danger, has been confirmed by the absence of pain or other annoyance. The discharge, which was sanious and copious in the first instance, has of late been only about three minims of clear serum in twenty-four hours ; and judging from our previous experience with compound fractures, there is every reason to expect that in a few days more it will cease entirely.

[The subsequent progress of the case has been, on the whole, very satisfactory. But, for reasons to be soon referred to, healing by scabbing did not take place as was anticipated. The discharge, instead of drying up, showed rather a disposition to increase, and assumed a somewhat puriform character ; and, although the renewal of the superficial plaster once in two or three days did not involve much disturbance of the limb, I thought it best to expose the wounds when sufficient time had passed to ensure the secure coalescence of their deeper parts. Accordingly, on the 1st of May I removed the lower portions of the dressings, disclosing two superficial granulating sores, with very prominent granulations, which explained the want of disposition to cicatrize. These, though treated with astringents, proved rather indolent, so that they were not completely healed till the 4th of June, though the bones were firmly united a fortnight before.

When he was allowed to walk, though he placed the sole fairly on the ground, he experienced inconvenience from a contracted state of the sural muscles, produced by the long-continued displacement of the foot backwards and consequent downward pointing of the toes, so that he could not bend the ankle beyond the right angle at which it had been maintained since the operation. I hoped that this inconvenience would be overcome by exercise ; but in this I was disappointed ; for though his power of walking improved, it was by no

means satisfactory. It also appeared that the abnormal position of the foot had led to an exaggeration of the curve of its arch, to such an extent as to make the foot half an inch shorter than the other, while the plantar fascia was felt as a rigid band. I therefore divided that fascia and the tendo Achillis subcutaneously on the 26th of July, and this had the immediate effect of restoring the foot to its natural length, and permitting the ankle to be bent at an acute angle. Had I the case to treat over again I should perform the tenotomy at the same time as the main operation. But except the loss of time that has occurred, the result is nearly all that could be wished. Under the use of a Scarpa's shoe he has continued to improve steadily, and when I last saw him, in the early part of September, he could walk firmly and well, and complained only of some remaining stiffness of the ankle.] [1]

In compound fracture, as a general rule, healing by scabbing is that which should be aimed at. When this is attained, the treatment becomes greatly simplified ; while the patient is saved any drain upon the system from purulent discharge, and any risks that may attend the presence of a granulating sore. With this object in view, it is necessary that the deeper layers of the dressing should be left to form the scab, and that, while the antiseptic is renewed from time to time externally, it should not penetrate to the surface of the wound ; otherwise the carbolic acid will stimulate the tissues to granulation and suppuration, though without putrefaction.

But, it may be asked, Is it not objectionable to keep the wound permanently covered up ? Is it not desirable to examine it from time to time, and ascertain what is going on in it ? To this I would reply by another question. Does the surgeon think it needful, in a case of simple fracture, to make an incision and investigate the state of the broken bone, the torn muscles and fasciae, and the other elements of the contused wound which, though the integument remains entire, exist as surely as in a compound fracture ? No surgeon would think of such a course. And, on the same principles, provided no unfavourable symptoms are present, we may be well pleased to leave the deep portion of the dressing to serve as a temporary skin.

Yet it must be admitted, that to change the superficial layer of the dressing, without raising the deeper layers, is often a matter of great nicety, while the admission of septic air beneath the scab would be fatal to this mode of treatment. For, the dressing being purposely so arranged that the parts in im-

[1] The Address as actually delivered continued the discussion of the principles of the dressing, and gave details of the mode of procedure, supposing the lead-plaster to be employed in the form in which it was then described. In order to enable me to introduce subsequent improvements, I have thought it best entirely to remodel the remainder, though retaining to a certain extent its original features.—J. L.

mediate contact with the wound may be free from carbolic acid, receiving none from without to compensate for loss by absorption of that which they originally contained, the lower surface of the application becomes, in a day or two, devoid of all antiseptic properties, and the penetration of living germs beneath it would lead to putrefaction there, which would spread to any extravasated blood or dead tissue that might remain unabsorbed in the wound. Rather than run any serious risk of such an occurrence, it would be far better to change the whole dressing every day. For although this would necessitate granulation and suppuration, through the continued action of the acid upon the raw surface, yet the essential object of the antiseptic treatment would be attained ; that object being not the avoidance of suppuration, but the prevention of putrefaction in the wound. It is of great importance to bear in mind this distinction, which, from want of clear ideas regarding the conditions which determine suppuration, is very liable to be overlooked. A patient may die of poisoning and irritation in compound fracture, from putrefaction of the blood extravasated in the limb, before sufficient time has passed for any pus to be formed ; and, on the contrary, suppuration may take place in connexion with compound fracture, whether from the action of the stimulating antiseptic on the wound or from the occurrence of abscess in the contused limb independently of atmospheric influence, without the patient's life being at all endangered, provided always that antiseptic treatment is perseveringly continued.

Nevertheless, the advantages of healing by scabbing are so great that it is worth while to endeavour to attain them, and I have been long striving to improve the method of dressing, so as to get rid, if possible, of the attendant risk. A plan which has, in most cases, answered well when the putty has been used, is to make the permanent dressing of two or three layers of lint somewhat larger than the wound, wrung out of a pretty strong solution of carbolic acid in oil, say one of acid to four of oil, and covered with a piece of oiled calico or linen rag extending about an inch beyond the lint in every direction. Over this is applied a stratum of antiseptic putty, which is changed daily, or once in two days, according to the amount of discharge. The blood from the wound soaking into the lint is acted on by the carbolic acid, and changed into a firm substance which consolidates the deep dressings into a crust or scab, and this crust, while sufficiently thick over the wound to prevent the carbolic acid of the putty from penetrating to the raw surface, is so thin at its margins formed by the rag as to be there kept antiseptic through and through. Then, in changing the putty, the first thing seen on lifting up its edge is the thin margin of the calico ; and even if this be accidentally raised a little, its antiseptic property prevents any mischief from resulting. The putty is spread on calico, and the calico is applied

next to the deep dressing, to prevent adhesion, while the external surface of the putty is covered either with thin block-tin or sheet-lead, or, what more recently we found to answer quite as well, gutta-percha tissue, which, though it permits carbolic acid to escape through it, is not objectionable on that account if the putty be sufficiently thick, while the gutta-percha, like the metallic plate, prevents the putty from becoming dry and hard. The putty is made to overlap the permanent dressing well on all sides, and I may remark that, whether the impermeable antiseptic guard be composed of putty or not, it is of the utmost importance that it should extend freely beyond the source of the discharge in every direction, so that the putrescible fluid may have to flow for some distance beneath it before it reaches the atmosphere or any dressing containing active putrefactive organisms. The degree of overlapping of the crust by the external dressing must vary according to the amount of discharge which may be anticipated. When this is large, it should be to the extent of three or four inches. Failures have undoubtedly often occurred for want of attention to this essential point.

But though this method will, with proper care, generally succeed,[1] it would be very desirable, if possible, to get rid of the trouble involved in it. At one time I hoped this might be done by means of the plaster above mentioned, by employing a layer of it instead of the calico as the upper part of the permanent dressing, so that the adhesiveness of the emplastrum might keep the whole deep dressing securely applied to the skin, except at limited spots where the discharge might ooze out ; another layer of plaster being used instead of the putty, with calico moistened with a watery solution of the acid interposed to prevent adhesion of the two layers of plaster. My anticipations, however, have not been verified in this respect. For the plaster, though it answers extremely well for an external antiseptic guard, whether in compound fracture, incised wounds, or abscesses, has proved unsuitable for the permanent dressing. The substance of the emplastrum becomes softened by the solution of carbolic acid used to moisten the calico, and permits it to enter beneath it and soak into the lint below, and stimulate the raw surface to granulate and suppurate, and this was what occurred in the case of displaced foot above mentioned. At the same time the lint is kept moist, instead of forming a dry crust, and hence it may gradually shift its place along with the plaster that covers it, involving the risk of leaving the wound insufficiently overlapped, if not exposed.

[1] For an admirable example of success with this method, the reader is referred to the *Lancet*, August 29, 1868, where Mr. Cresswell, of Merthyr Tydvil, reports a case of gunshot-wound of the femur, shattering the trochanteric region and neck of the bone ; the wound by which the ball entered posteriorly and that in the groin by which it was extracted by incision, both healing completely by scabbing, under a crust of oiled lint, covered with antiseptic putty, daily renewed.

I have experienced this inconvenience in two cases of compound fracture which have been treated in this way. One of these was an old lady, of seventy-five, in whom the os humeri was severely comminuted just above the elbow-joint, with a considerable wound from which six loose fragments were extracted; the other was a boy, twelve years old, whose right thigh was much contused as well as broken by machinery. These cases, indeed, have done well; osseous union having occurred as early as if the fractures had been simple ones. But in both of them the wounds healed by granulation instead of by scabbing.

With the view of getting over these difficulties I sought to obtain some kind of antiseptic cement, by which a portion of dressing might be glued down firmly upon the skin. Among other materials I tried shellac, and, in so doing, I accidentally hit upon a substance which appears preferable to the plaster for almost every purpose. I found that this resin could be mixed with carbolic acid in any amount by aid of heat, the result, when cooled, varying, according to the quantity of the acid, from brittleness to fluidity, the intermediate proportions giving a firm but flexible solid with a certain degree of elasticity, approaching to some extent the characters of caoutchouc. It further turned out that the lac thus associated with the carbolic acid retained it with great tenacity,[1] so that a thin layer spread on calico may be used to store up a large quantity of the antiseptic, forming an application which retains its virtues for days at the temperature of the body, and, at the same time, fails to irritate the skin. It has also this great advantage over the lead plaster, that it cannot be softened by either a watery or an oily fluid. The only imperfection which it appeared to show, when used in practice as an external antiseptic guard, was that when long applied to the skin it adhered to the surface, whereas it is desirable that such a dressing should adhere very slightly if at all. This objection to it I attempted to obviate by spreading it upon gutta-percha tissue, which, though insoluble in carbolic acid, allows it to travel through its substance. The lac when thus lined with gutta-percha proved none the less efficient as an antiseptic, and, being perfectly devoid of adhesiveness and of smooth surface, shed the discharge in a most perfect manner, greatly excelling, in this respect, the lead-plaster. But it had one fault, viz. that when subjected to much bending, as at the fold of a joint, the gutta-percha cracked and admitted the discharge, which, gradually insinuating itself, detached the gutta-percha more or less extensively, and introduced an element of risk through the interposition of a layer of liquid between the antiseptic lac and its lining. This fault has been got rid of by reducing the gutta-percha to a mere film, incapable of affording lodge-

[1] In this respect, lac differs altogether from india-rubber, which, though it may be impregnated with the acid to any degree, parts with it rapidly.

ment for fluid, by brushing over the antiseptic lac with a weak solution of gutta-percha in bisulphide of carbon, which, rapidly evaporating, leaves a coating of microscopic thinness, yet effectual for preventing adhesion. We have now given this lac dressing a sufficient trial in wounds and abscesses to entitle me to recommend it with confidence.[1]

For an antiseptic dressing that is intended to be changed from time to time, perfect absence of adhesiveness is a most valuable property; not only because it permits all discharge to escape beneath it into the porous material placed outside to absorb it, but because it avoids traction upon any deeper dressing or upon the skin during the process of withdrawing it, with the concomitant risk of regurgitation of air or liquid charged with living putrefactive organisms.

But for the permanent dressing in compound fracture this complete want of adhesiveness is the converse of what we desire. Here, the material employed, being designed to form part of the scab, should stick to the skin or to anything else that lies beneath it. The lac prepared as above described may, however, be readily made suitable for this purpose, by rubbing off the film of gutta-percha by firm friction with a dry cloth, and then brushing the surface over with liquid carbolic acid. It then, at once, assumes a sufficient degree of adhesiveness.

In order to ensure healing without suppuration, it is requisite, as we have seen, not only to prevent the spreading of putrefaction into the wound, but also to protect the raw surface from perpetual stimulation by the carbolic acid. In the mode of dressing, above described, in which the putty was employed, the latter object was attained by means of layers of lint forming a crust too thick to be penetrated by the acid supplied externally; and the same plan would, no doubt, succeed as well with the lac. But to trust to the mere thickness of a penetrable crust is not altogether satisfactory. It would clearly be better, if possible, to protect the exposed tissues from the stimulating antiseptic in the lac by a layer of some substance chemically impermeable to carbolic acid. A metallic plate possesses this property; and in its more flexible forms, such as thin block-tin or sheet-lead, it seems likely, at least in ordinary cases, to

[1] This plaster is supplied at a very moderate price by the New Apothecaries' Company, Glassford Street, Glasgow, to whom I am much indebted for the interest and pains they have taken in bringing it to perfection. The following is the mode of its manufacture: Take of shellac, 3 parts; crystallized carbolic acid, 1 part. Heat the lac with about a third of the carbolic acid over a slow fire till the lac is completely melted; then remove from the fire and add the remainder of the acid, and stir briskly till the ingredients are thoroughly mixed. Strain through muslin, and pour into the machine for spreading plaster; and, when the liquid has thickened by cooling to a degree ascertained by experience, spread to the thickness of about one-fiftieth of an inch. Afterwards, brush the surface of the plaster lightly with a solution of gutta-percha in about thirty parts of bisulphide of carbon. When the sulphide has all evaporated, the plaster may be piled in suitable lengths in a tin box without adhering, or rolled up and kept in a canister.

answer well. I have, as yet, only had opportunity to try this method in two cases, but both of these have presented points of interest which make them deserving of mention.

Case of Contused Wound treated with Block-Tin and Antiseptic Lac.—The first was a contused wound, three inches long, over the lower part of the tibia, with some undermining of the skin, in a young man of twenty, occasioned by the limb being violently squeezed between a heavy iron pipe and a fixed piece of machinery. Happening to be at the infirmary soon after his admission, I dressed the case myself, washing and syringing out the wound with a saturated watery solution of carbolic acid, and covering it with a well-fitting piece of thin block-tin of rather larger size, washed with the watery solution, and then applying a piece of lac-plaster, deprived of its gutta-percha layer, overlapping the tin freely on all sides. A piece of calico was placed outside the lac-plaster, to prevent adhesion of its edges to a dry cloth, which was wrapped round the leg to absorb discharge, and was intended to be changed. Next day there was a good deal of sero-sanguineous effusion on the cloth, for which another was substituted, moistened with a solution of carbolic acid in four parts of olive oil. The same was afterwards done daily; the discharge diminishing rapidly, and the limb remaining free from swelling or pain, and the constitution from disturbance, till, on the fourth day, the patient, who was a silly youth, was seized with a desire to see the injured part, and tore off all the dressings. This foolish proceeding on his part gave us the opportunity of making an interesting observation. The wound was found perfectly level with the general surface of the skin, being filled with a clot of smooth surface corresponding to that of the tin which had covered it, while the edges of the skin were pale and natural in appearance. The dressing was re-applied as before, the wound being superficially washed with carbolic acid lotion in the process. Two days later the patient again, without any reason, laid bare the wound, which still presented the same characters, except that the surface of the smooth clot showed, here and there, some minute whitish specks, probably in consequence of the action of the watery solution of carbolic acid with which it was washed two days previously. A similar dressing was again employed, the use of carbolic lotion being again necessarily involved. After two more days, that is to say a week after the accident, the patient, though free from symptoms, having again removed the dressings, the wound was again examined. It was free from pus or odour of putrefaction, but its surface was mottled with red and yellow spots, and was not quite level. The dressing was continued one day longer, when it was abandoned, as the patient could not be induced to leave it alone, water dressing being used instead; and on the following day the wound presented the characters

of a healing superficial granulating sore. Two days later, he was so unruly that he was discharged for misconduct.

In the following case we have had the opportunity of seeing the effects of this mode of dressing when left undisturbed.

Case of Compound Fracture of the Leg treated with Block-Tin and Antiseptic Lac.—On the 3rd of October, 1868, a porter, twenty-five years old, was unloading a wagon in a warehouse, when a box, weighing about four hundredweight, slipped, and, striking him upon the left leg, knocked him down over an opening in the floor, through which he would have fallen into the room below had not the heavy box, pressing upon the limb, pinned him down and kept him suspended. When rescued from this situation, he was taken to the infirmary, where my house surgeon, Mr. Malloch, found the leg much distended with extravasated blood, with a wound, three-eighths of an inch in length, on the inner side, about midway between the knee and ankle, bleeding freely and communicating with a transverse fracture of the tibia. A probe (smeared with an oily solution of carbolic acid to prevent the introduction of septic particles) could be introduced beneath the undermined fascia for about three inches in every direction except downwards, and also passed, for the same extent, directly outwards behind the tibia which was felt to be denuded of its periosteum. Having injected into the wound, with a syringe, several ounces of a saturated watery solution of the acid, and diffused it freely through the limb by pressure, to mix it with the extravasated blood, Mr. Malloch placed a piece of thin block-tin about an inch square over the orifice, and, after pressing out as much as possible of the blood and watery solution, applied a piece of lac-plaster deprived of its gutta-percha lining, overlapping the tin a couple of inches in every direction, and over this a folded cloth moistened with a solution of carbolic acid in four parts of olive oil. The limb was then put up in lateral pasteboard splints. This treatment relieved the severe pain which he was suffering ; but it returned in the course of the next few hours, during which very free haemorrhagic effusion occurred. Next day the discharge became greatly diminished, and in the course of the following day it ceased entirely. The pain also left him about twelve hours after the accident and never returned. The after treatment consisted for the first two days, in renewing the oily cloth once in the twenty-four hours ; but from the third day onwards the cloth was left permanently upon the limb and merely brushed over with a mixture of equal parts of carbolic acid and oil, the inner splint being raised for the purpose without disturbing the limb, which lay upon its outer side with the knee bent. After the sixth day, the antiseptic oil was only applied once in forty-eight hours. On the third day, some wrinkling of the epidermis indicated subsidence of the swelling, which afterwards fell

rapidly till, by the eleventh day, the calf was almost of natural size, having shrunk away considerably from the splint. His pulse never rose above 82, which was its number the day after the accident, and his general health was from that time forward quite unaffected.

Ten days after the receipt of the injury, it was noticed that the oily cloth, which for a week past had indicated complete absence of discharge, exhibited an appearance of additional staining, corresponding to two or three drops of red serum which seemed to have been pent up beneath the lac-plaster by inspissation of the blood and serum round its margins, till some accidental cause, such as the shrinking of the limb, cracked the dried exudation. Having been led to disturb the dressing to some extent in investigating the source of this discharge, I thought it best to remove it entirely, protecting the wound at the moment of its exposure with a bit of antiseptic lint. The under surface of the lac gave distinct indications of being impregnated with carbolic acid. The wound presented a very interesting appearance. It had shrunk considerably; but its margins resembled those of a perfectly recent wound; and its orifice was occupied by a projecting dark clot, which to the naked eye scarcely differed from a fresh coagulum. Hence there seemed reason still to hope for healing without suppuration, if the original mode of dressing were repeated. Accordingly, the tin smeared with carbolic acid was replaced, and overlapping it a fresh portion of lac-plaster, rendered adhesive by touching it with carbolic acid after removing the film of gutta-percha, except in a narrow space from the centre to one side, where the gutta-percha was left, to provide for the escape of discharge. A dry cloth and the splint completed the dressing. Two days later, in order to maintain the lac-plaster in an antiseptic condition, two layers of calico, moistened with a solution of carbolic acid in four parts of olive oil, were substituted for the cloth; and afterwards, at intervals of from two to three days, the surface of the calico was lightly brushed over with a mixture of equal parts of the oil and acid. For six days, some yellowish serum, amounting at first to one or two minims in twenty-four hours, but gradually diminishing, exuded from below that part of the margin of the lac-plaster where the gutta-percha film had been left, the amount being estimated by changing every day a little bit of antiseptic lint placed at the point of exudation. But, after the sixth day, the piece of lint was left unchanged, as the trifling discharge seemed to have ceased entirely. When eleven days more had passed without any change, I thought it well to ascertain again the state of the wound; and on the 30th of October, seventeen days after the second application of the deep dressing, and two days short of four weeks after the accident, I pulled off the lac-plaster with the tin adhering to it. The plaster was still sticking to the skin, and drew

away the hairs along with it, except where the gutta-percha film remained. At this part, along the course of the track of exudation, the skin had an orange stain, from serum mixed with altered haematin, and was moist, except near the edge of the plaster. Beneath the tin, also, there was the same kind of orange moisture. The wound appeared at first sight unhealed, having an orange-red aspect ; but, on wiping it with a piece of lint, a perfect cicatrix was disclosed, which had been covered with the remains of the little portion of clot seen projecting from the orifice on the former occasion of exposing it. A piece of dry lint was placed upon the scar ; and the splints were readjusted, the fragments being in good position. The case was now reduced to one of simple fracture.

This case presents several features of great interest. In the first place, the appearances disclosed on the removal of the dressings on the tenth day after the accident afford as good an illustration as could be desired of the fact that the surface of a wound is not induced to suppurate, or indeed to undergo any appreciable change by the contact of a foreign body, destitute of chemically stimulating properties. The carbolic acid with which the surface of the tin was washed, like that injected into the wound, was absorbed into the circulation before it had time to bring about those changes in the part which are the essential preliminary to suppuration. The tissues of a recent wound are incapable of forming pus, however much they may be stimulated, whether by nervous (i.e. inflammatory) excitement, or by chemical irritants, such as the products of putrefaction or pungent antiseptics. It is only when they have been gradually changed under the influence of prolonged abnormal stimulation into that rudimentary form of tissue which, when we see it on the surface of a sore, we term granulations, that they are liable to produce, when still further stimulated, the still more rudimentary pus corpuscle. It is upon this that the possibility of obtaining primary union on the antiseptic system depends. The antiseptic applied to the wound in the first instance is a powerful stimulant, but it is absorbed before it has time to bring about granulation in the tissues.

In the second place, it is very satisfactory to see, although theoretically it could hardly have been doubted, that, when a wound has been effectually protected from stimulation and consequent granulation, it may, even at a late period after its infliction, be again subjected to the temporary stimulus of an antiseptic application without being made to suppurate ; for a knowledge of this fact will enable us to examine the wound when we think there is a fair prospect of healing being complete, confident that, should the reverse prove to be the case, we can again employ the original mode of dressing without interfering with the process of healing by scabbing.

Thirdly, I may remark that cicatrization without suppuration beneath

a piece of tin is a novel mode of healing by scabbing. But the ordinary scab is in so far analogous to the metallic plate, that the exudations of which it is composed having dried before they had time to putrefy, the crust is, like the metal, a neutral or unstimulating solid. Further, there is putrescible moisture beneath the scab as beneath the tin ; but the mode in which the putrefactive organisms are excluded is essentially different. The scab keeps them out mechanically, by adhering firmly to the surface of the integument ; the metallic plate opposes no mechanical barrier to their entrance, but is guarded by a germ poison in the surrounding lac which no less imperatively forbids their access.

Altogether the case must be regarded as affording great encouragement for giving a further trial to this method, which seems to bring the treatment of compound fracture to something nearly approaching perfection. The lac, being impermeable to discharge, combines the properties of an external antiseptic guard with those of a permanent crust ; and, as fresh carbolic acid can be supplied to it as often as may be desired without disturbing its position, the trouble and risk that attended the changing of the putty are entirely got rid of. At the same time the tin protects the raw surface from the acid with absolute certainty, while the tin and the lac constitute together so thin a layer as not to alter the contour of the limb, or interfere with the shape of splints such as would be used for simple fracture ; a considerable advantage as compared with the mass constituted by a thick crust, covered with substantial putty. When the wound is large, I would advise the use of two layers of the lac-plaster for the sake of additional strength, the outer one overlapping the inner by an inch or two ; and the outer, like the inner, rendered adhesive, as above described, so that the two may become incorporated into one mass. Also, I would recommend that, as was done in the second dressing of the last case, the film of gutta-percha should be left upon a track leading from the tin to what is to be the most dependent part of the edge of the plaster to afford free egress for sero-sanguineous discharge.

For treating the interior of the wound in compound fracture, I employed, till comparatively lately, the undiluted acid, and, as this afforded excellent results, I did not venture to change the practice without having some more substantial basis than hope to found upon. But rather more than a year ago, having observed that the injection of a saturated watery solution (one part of acid to twenty parts of water) among the fibrous tissues in a fetid suppurating wound of the palm, completely arrested the existing putrefaction, I concluded, that if the acid so diluted sufficed to destroy the abounding putrefactive organisms which must have been present among the textures in that case, it must surely be trustworthy for compound fracture. We have accordingly

employed the saturated watery solution in all the numerous cases of compound fracture that have since come under my care, and in no instance has it failed. If it answers equally well, it is obviously superior to the strong acid, since it does not produce the slightest sloughing from caustic action, and, being a less powerful irritant, causes a less copious serous effusion. Besides, it may be injected and diffused among the tissues which are the seat of extravasation with a freedom which could not be used with the acid of full strength, and it is to this circumstance that I am disposed to attribute the fact that we have obtained success at a period after the infliction of the injury which I should formerly have thought quite hopeless, in one case, for example, as late as thirty-six hours after the accident. Lastly, we avoid a disagreeable symptom which we used to observe occasionally after applying the undiluted acid freely to large wounds, viz. obstinate vomiting for about twenty-four hours, occasioned, no doubt, by imbibition of a poisonous dose into the circulation.[1]

Catgut, manufactured from the small intestine of the sheep,[2] may be had at a very low price, from the thickness of a horsehair upwards. In the dry state, it is somewhat objectionable from its rigidity, and also from a tendency of the first half of the knot to slip before the second half is secured. Water renders it perfectly supple, and as little liable to slip as waxed silk. But if a watery solution of carbolic acid be used for the purpose of making it antiseptic, the protracted immersion requisite to ensure completeness of the effect makes the finer kinds too weak, and the stouter too clumsy so that it will not enter the eye of an ordinary aneurysm-needle. The method which I have found to answer best is to keep the catgut steeping in a solution of carbolic acid in five parts of olive oil, with a very small quantity of water diffused through it. A larger proportion of the acid would impair the tenacity of the thread. If a mere oily solution be employed, the gut remains rigid, the oil not entering at all into its substance. But a very small quantity of water, such as the acid enables the oil to dissolve, renders the gut supple, without making it materially weaker or thicker. And, curiously enough, the presence of this small amount of water in the oily solution gradually brings about a change in the gut, indicated by a deep brown colour, after which it may be placed in a watery solution for a long time, without swelling as a portion prepared in a simple oily solution does. This is a great convenience. For an oily solution is unpleasant to work with

[1] A report of the case of ligature of the external iliac artery mentioned in the footnote to p. 65, together with an account of the conditions found post mortem, as also a report of the ligature of the carotid artery in the calf are omitted in this place since they are given more conveniently at pp. 88–98 of this volume.

[2] I need hardly remark that catgut is of a totally different nature from the so-called silkworm gut, which is in reality unspun silk. [The reader may consult also pp. 107–8.]

during an operation ; and exposure to the air soon renders gut suppled with water rigid from drying. But, when it has been treated in the way above recommended, it may be transferred to a watery solution at the commencement of an operation, and so kept supple without having its strength or thickness altered.

For tying an arterial trunk in its continuity, catgut as thick when dry as ordinary purse-silk will be found best ; but for ordinary wounds, where, if one ligature happen to break, another can be easily applied, much finer kinds may be employed, and are convenient from their smaller bulk. For everyday use, a small oil-tight capsule may be carried in the pocket-case ; and this case can be replenished from a larger stock as may be necessary. I have had a small silver bottle with well-fitting screwed top adapted to my caustic case ; and this contains two little rods of wood with gut of two sizes wound upon them, together with a few drops of the antiseptic oil : and now that torsion has almost entirely superseded the ligature in ordinary wounds, this small supply will probably last me for months.

OBSERVATIONS ON LIGATURE OF ARTERIES ON THE ANTISEPTIC SYSTEM

[*Lancet*, 1869, vol. i, p. 451. Corrected February 1870.]

VARIOUS attempts have been made, both in the early part of the century and more recently, to improve the ligature, or to supersede it by other methods. Nevertheless, for obstructing the calibre of an arterial trunk in its continuity, no means hitherto devised have proved superior to a small silk thread tied in a secure knot, with the ends left projecting from the wound. Yet, as is implied by the numerous efforts at improvement, the ligature in this form is far from perfect. The internal and middle coats are ruptured by the constricting noose, while a portion of the tough external coat is pinched together and deprived of its vitality. The dead tissue, becoming contaminated by the putrefaction which occurs in the interstices of the silk fibres, acts, together with the septic ligature, as a cause of irritation to the neighbouring parts of the arterial wall, which consequently degenerate into an imperfect structure, inadequate to withstand the powerful cardiac impulse ; and even before the slough separates by suppuration, the blood breaks through the feeble barrier, unless it be fortified by a firm plug of internal coagulum. Hence, if a considerable branch takes origin close to the part tied, the formation of a clot being prevented by the current of blood, secondary haemorrhage is the inevitable consequence ; and thus the ligature is inapplicable in situations otherwise eligible for it, such as the femoral artery near Poupart's ligament, the origins and endings of the iliacs, and the innominate.

Even when the thread is distant from any considerable branch, the terrible risk of haemorrhage cannot be said to be altogether absent. The degenerate structure of the vessel near the ligature, unlike the arterial wall in its normal condition, is prone to ulceration, and the organizing coagulum is similarly circumstanced ; so that an unhealthy state of the wound may open up the calibre of an artery tied in the most favourable situation.[1]

[1] It has been long since noticed that haemorrhage occurs more frequently from the distal than from the cardiac end of the vessel. This seems at first sight contrary to what might be expected, since the cardiac end is subjected to much greater strain. The explanation is, I believe, afforded by some facts which I had occasion some years ago to point out. (See the Croonian, Lecture 'On the Coagulation of the Blood,' printed in vol. i, p. 109.) It was then shown that a perfectly undisturbed coagulum resembles healthy living tissue in failing to induce coagulation in blood near it ; but that, on the other hand, while a clot is, from its softness, peculiarly liable to laceration and other disturbance, a disturbed coagulum acts like injured tissue in impressing upon neighbouring blood a coagulating tendency. Hence, when a ligature has been tied round an artery, although a minute clot

Again, when the parts about the vessel communicate with loose cellular interspaces in important regions, as is the case with the iliac arteries or the subclavian, diffuse suppuration is frequently a cause of death. Finally, the cure is always rendered tedious by the time required for the separation of the ligature ; while the presence of an external wound during the period thus protracted involves a risk, by no means inconsiderable in some localities, of hospital gangrene or erysipelas.

The Antiseptic System, however, places this branch of surgery, like most others, in a new light. One point which it has brought out in striking relief is, that a portion of dead tissue is not necessarily thrown off by suppuration, but, unless altered by putrefaction or artificially imbued with stimulating salts, serves as pabulum for the surrounding living parts, which remove it by a sure process of absorption. Hence, the death of a portion of the external coat included in the ligature does not of itself render it a cause of suppuration. And I conceived that if a silk thread, steeped in some liquid capable of destroying the septic organisms in its interstices, were tied round an artery, and left with short-cut ends in a wound dressed antiseptically,[1] the foreign body, soon losing, by diffusion into the circulation, the stimulating salt with which it was saturated at the outset, and being in its own substance as unstimulating chemically as a pellet of lead from a fowling-piece, would either remain, like the latter, permanently encapsuled, or itself experience absorption together with the dead tissue in its grasp. In either case, being destitute of irritating properties, it should leave the primitive strength of the arterial coats unimpaired ; when the objection to tying near a large branch would cease to exist. The wound meanwhile would, under proper management, close rapidly, without any deep-seated suppuration, and would be efficiently protected against the evil influences of impure atmosphere. In short, the ligature of an arterial trunk in its continuity would be brought to a state of perfection.

I have subjected these theoretical views to the test of experience ; and though the results have not turned out in all respects exactly as I had anticipated, yet those finally arrived at appearing satisfactory, I now present to the profession an account of all that I have done in the subject.[2]

necessarily forms upon the injured internal and middle coats, it would undergo no increase if the blood in the vessel were absolutely quiescent. But the pulsations of the artery operate as a disturbing cause to the clot already formed, which consequently increases in proportion to the degree of the disturbance ; and as this is much greater at the cardiac side, the clot grows more quickly there, and forms a more secure barrier against the pressure of the blood.

[1] In using the expression 'dressed antiseptically', I do not mean merely 'dressed with an antiseptic', but 'dressed so as to ensure absence of putrefaction'.

[2] A brief account given in the original of the case of ligature of the carotid artery in the horse with silk thread on the antiseptic system more fully reported at p. 64 of this volume, has been omitted in this place.

Case of Ligature of the External Iliac Artery on the Antiseptic System.[1]—On the 29th of January, 1868, I was requested by Dr. Fergus to see a lady fifty-one years of age, who was suffering from an inguinal aneurysm which had existed for four years, but had of late been markedly on the increase, causing agonizing pain, which had confined her to bed for the last four weeks, and had considerably reduced her strength. The aneurysm was of the size of a large orange, affecting the uppermost part of the left femoral artery, and extending a little above Poupart's ligament. Any delay appearing undesirable, I tied the external iliac on the following day, in presence of Dr. Fergus, and assisted by Messrs. Hector Cameron, Appleton, and James Coats. There was nothing peculiar in the operation, except that the incision was made a little further outward than usual, in order to avoid the upper part of the aneurysm. The only bleeding vessel that required attention was twisted. The ligature employed had been previously steeped for two hours in strong fluid carbolic acid, prepared by adding a small proportion of water to the crystals. The tightly twisted thread requires a considerable period of immersion to ensure thorough soaking with the liquid; and the acid does not impair the tenacity of the fibre. At the time of the operation, the superfluous acid was removed by transferring the silk to a solution of carbolic acid in thirty parts of water; and the same lotion was used for the sponges, and also for washing the aneurysm-needle before it was passed round the vessel. The artery having been tied, and the ends of the ligature cut short, the wound was freely treated with the watery solution, some of which was poured in, to make sure that it penetrated to every part. The edges of the skin were then brought together with silver sutures, except in the middle, where I introduced a pledget of lint steeped in a solution of the acid in five parts of olive-oil; passing it deeply, but leaving one end projecting externally, to serve as a drain for blood and serum. I then applied an external antiseptic dressing, the details of which I need not now describe. The pledget of lint was cautiously withdrawn on the following day, under cover of a pretty large piece of lint imbued with the antiseptic oil; and the external dressing was reapplied, and afterwards changed at intervals proportioned to the diminution of the serous discharge, which, at the end of a fortnight, was estimated at about three minims in three days. At this time, some portions of lint, which had been left till then undisturbed, were removed, when the wound was found quite free from pus, being perfectly cicatrized where the sutures were introduced; while the central part, where the pledget was placed after the operation,

[1] The report of this case down to the account of the condition of the patient on July 25, 1868, has been inserted here from the address on the Antiseptic System of Surgery (p. 51), and has been omitted from that address (p. 65).

presented the appearance of a superficial sore, but not a granulating one; for the deep surface of the dressing, being devoid of stimulating properties, had failed to induce granulation in the tissues on which it lay. Meanwhile the patient had been relieved from the pain which she previously suffered, without experiencing febrile disturbance or any material inconvenience from the operation, except uneasiness in the wound the first two days, during retching occasioned by the chloroform. The tongue had been natural throughout; the pulse had only on one day been as high as 90, 72 to 84 being the usual rates; and her appetite, which had been absent during the four weeks of agony that preceded the operation, returned two days after it, as soon as the derangement of the stomach from chloroform subsided. On the fourteenth day, as I was arranging her pillows, she sat upright without inconvenience. Four weeks after the operation, the wound being completely cicatrized, she was allowed to move about in her room; and, just six weeks from the date of the ligature of the artery, she descended three long flights of stairs, walked for some time in the streets, and reascended the steps to her lodgings; and, though fatigued by the effort, she felt next day all the better for it. On the 31st of March, she called to see me, much improved in strength, though with still some tendency to swelling of the legs, especially the left, when in the erect posture. The aneurysmal swelling felt merely like a slight glandular thickening. On the 25th of July, 1868, I again visited her. She had derived much benefit from a stay at the seaside, and the tendency to oedema of the extremities was greatly diminished. There was still absence of pulsation in the external iliac artery, and the cicatrix remained quite sound twenty-five weeks after the operation.

She continued for about ten months in fair health and strength; but, in the latter part of November, she became affected with a peculiar spasmodic disorder of the respiration, and on the morning of the 30th of the month, while sitting up in bed, she suddenly exclaimed that something had given way within her, and that she was dying, and then immediately expired. Next day I made a post mortem examination, when the idea which she had expressed proved correct—an aneurysm of the descending part of the arch of the aorta having given way, and discharged an enormous quantity of blood into the mediastinal and subpleural cellular tissue. The parts concerned in the operation having been removed and dissected, the following appearances were disclosed. The aneurysm was not entirely obliterated; but remained about the size of a cherry or large filbert, of somewhat fusiform shape. The upper two-thirds were solid, being occupied by firm coagulum incorporated with the sac. The lower third, situated just at the bifurcation of the common femoral, had been kept free from coagulation by the regurgitant stream of blood from the profunda into the

superficial trunk. This part of the sac appeared constituted by the wall of the vessel, very slightly distended. The external iliac artery was considerably shrunk throughout, and tapered from each end to near the middle, where it was only about a twentieth of an inch in diameter. In the greater part of its length the structure of the dwindled vessel could be distinctly recognised, with adherent coagula in the interior, decolourized and otherwise altered. But at the narrowest part the artery was reduced to mere fibrous tissue, constituting a dense white band five-eighths of an inch long, from the middle of which was seen projecting at one side a round, buff-coloured appendage about a line in diameter, somewhat obscured by a trifling amount of inflammatory condensation of texture in the immediate vicinity. On scratching this little body with the point of a knife, I found it to be a very thin-walled capsule, containing the knot of the ligature, with two tapering ends, which were shorter than the thread was cut at the operation, while the noose had vanished altogether. The surface of the knot also showed clear indications of having been subjected to an eroding agency, similar, no doubt, to that exerted by granulations upon dead bone absorbed by them.[1] Besides the remnant of the ligature, the tiny capsule contained a minute quantity of yellowish, semi-fluid material, looking to the naked eye like very thick pus. Under the microscope, however, pus-corpuscles were seen to form but a small proportion of its constituents, which were principally rounded corpuscles of smaller size, and fibro-plastic corpuscles, together with some imperfect fibres and granular material. In addition to these elements were some which at first puzzled me ; but which turned out to be fragments of silk fibre, of various lengths, and of jagged, tapering, or otherwise irregular forms, and many of them greatly reduced in thickness, contrasting strongly with the uniform bands of a fresh piece of silk from the same reel that had furnished the ligature (Fig. 1).

Mingled with the puriform fluid were also some delicate filaments of silk, visible without the microscope ; and these seemed to retain their natural elasticity. Nor was there anything about the more minute pieces into which the fibres had been so strangely chopped up, to indicate that they were undergoing a process of solution or softening by the fluid that soaked the thread. They had rather the appearance of having been superficially nibbled, so to speak ; confirming the impression conveyed by the naked-eye characters of the knot, that the silk had been eroded by the absorbing action of the surrounding parts. Indeed, considering the organic origin of silk, the remarkable thing seems to be, not that it should be absorbed by the living tissues, but that it should resist their influence so long.

[1] See *Lancet*, March 23, 1867 (p. 16 of this volume).

Why it was that the parts in immediate contact with the silk should have assumed so imperfect a structure is a difficult question, but one of great interest: because, although that structure could not be called pus, it was certainly a very near approach to it; and it is impossible to say that we had not here an incipient abscess. There can be no doubt that the presence of the thread was in some way or other the cause, and I think we can hardly be wrong in assuming that,

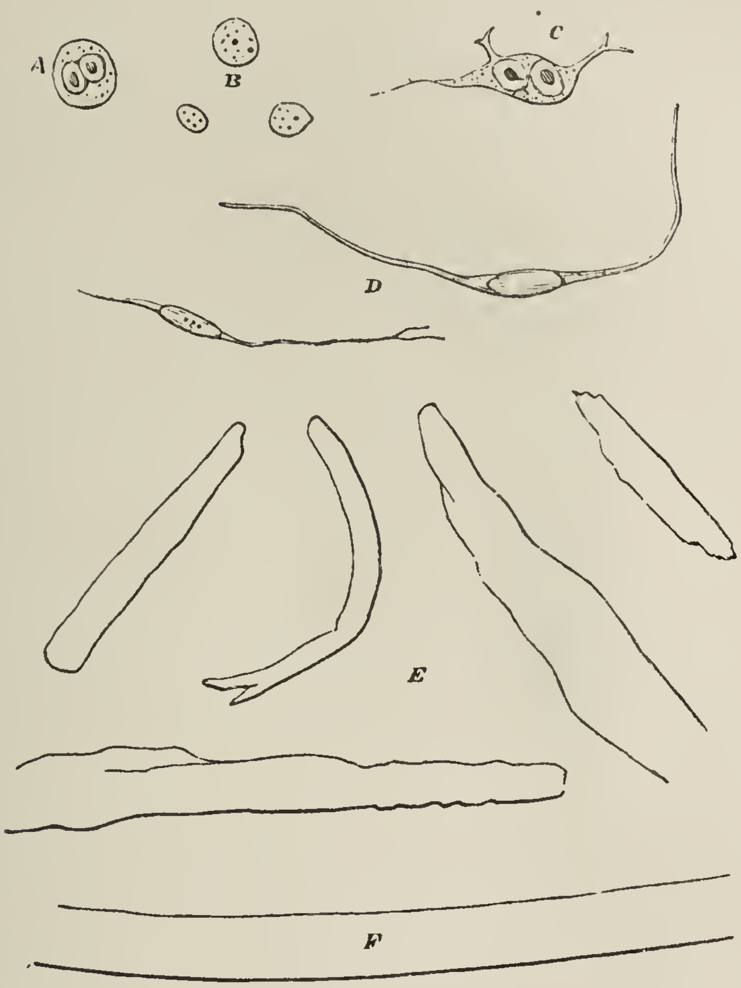


FIG. 1.—Constituents of the incipient abscess (?) around the remains of the silk ligature. Magnified 500 diameters. From a camera-lucida sketch. *A*, a pus corpuscle; *B*, rounded corpuscles of smaller size; *C*, fibro-plastic corpuscle with endogenous cell-development; *D*, ordinary fibro-plastic corpuscles; *E*, irregular fragments of silk fibre partially absorbed; *F*, a piece of fresh silk fibre introduced for comparison.

in order to give rise to such degeneration of tissue, it must have operated as a persistent, if trifling, source of abnormal stimulation. Now, as putrefaction is here out of the question, and as the substance of silk is not chemically stimulating, we seem shut up to the conclusion that the thread must have occasioned disturbance of a mechanical nature. Further, the effect in question seems to be essentially connected with the disintegration of the silk. For in the horse's carotid[1] the silk ligature, having remained unaltered during the six weeks that

[1] See p. 65 of this volume.

had passed after the operation, was found surrounded on all sides by compact tissue; and in the present case, so long a period as ten months having elapsed before the puriform condition was observed in an apparently incipient stage, it is probable that the thread had lain for a long time inert, producing irritation only when partially absorbed. If, then, we inquire how the disintegrating silk could prove a source of mechanical irritation, it seems not improbable that it may have been from the sharp and jagged fragments of the fibre perpetually fretting the elements of the living tissue around them. This view, if correct, would explain the curious fact observed by Lawrence and others, that when fine silk ligatures had been left with short-cut ends in a stump, though the wound might heal without their separation in the first instance, they were liable to make their appearance subsequently, sometimes at so late a period as seems to exclude the idea of putrefaction having occurred from organisms introduced into the threads. Indeed, such ligatures occasionally showed themselves encapsuled in little nodules in the cicatrix, without suppuration occurring at all.[1] In other words, the apparently soft silk, instead of remaining, like a smooth leaden pellet, permanently embedded in the place where it was first introduced, made its way to the surface with or without suppuration, like a sharp spiculum of rigid glass; the silk being in its minute structure comparable to the pellet when in the primitive condition of smooth continuous fibres, and to glass spicula when in the form of jagged fragments as the result of partial absorption.

But whatever may be thought of this explanation, it is clear that if there is any chance of silk, though used antiseptically, giving rise, even in exceptional cases, to abscess in the vicinity of an artery tied with it, this is a serious objection to its employment; and as the near approach to suppuration in the present instance was undoubtedly occasioned by the persistent presence of the thread, the case, while interesting as affording evidence that silk is susceptible of absorption, suggests the expediency of substituting for that material some other substance which can be more readily taken up by the tissues.

The use of 'animal ligatures', of catgut, leather, or tendon, was long since tried and abandoned as unsatisfactory;[2] but after the experience which the antiseptic system has afforded of the disappearance, without suppuration, of large dead pieces of skin and other textures, there could be little doubt that threads of animal tissue, if applied antiseptically, would be similarly disposed of.

And even if chemical processes should have been used in preparing such threads, it did not seem likely that this would interfere with their absorption;

[1] See Cooper's *Surgical Dictionary*, 7th edition, article Aneurysm.
[2] Op. cit., articles Aneurysm and Ligature.

for I knew that the free action of carbolic acid on blood and sloughs had no such deterring influence, and I have long been satisfied that the injection of a strong solution of perchloride of iron or tannic acid for the cure of naevi produces subcutaneous sloughs, which are imbued with the ingredients injected, and yet disappear, as a rule, without the formation of pus.

In order to put the antiseptic animal ligature fairly to the test, I made the following experiment :—

Ligature of the Carotid Artery in the Calf on the Antiseptic System, with Threads composed of Animal Tissue.—On the 31st of December, 1868, I tied the right carotid artery about the middle of the neck in a healthy calf a few days old, the animal being under chloroform. Ligatures of two different kinds were employed, at an interval of about an inch and a half, the sheath of the vessel being left undisturbed in the intervening part. The cardiac ligature was of home manufacture, composed of three strips of peritoneum from the small intestine of an ox, firmly twisted together into a three-fold cord. The distal thread was of fine catgut, called ' minikin gut ' by the London makers. Both had been soaked for four hours in a saturated watery solution of carbolic acid, which swelled and softened them, so that the thread of my own making was too large to enter the eye of the aneurysm-needle except near the ends, where it was thinner than elsewhere. This substantial ligature bore the strain of tying well, but the fine catgut broke as I tightened the noose. I did not, however, remove it, but having a second piece at my disposal, passed it round at the the same place, and with gentle traction completed the knot. There were thus two ligatures of the fine gut at the distal site. All were cut short, except one end of the catgut, which I purposely left about three-quarters of an inch long, to give a better opportunity of ascertaining what would become of the foreign material. The antiseptic arrangements were as follows : Before the operation the hair of the part was cut short, and a solution of carbolic acid in four parts of linseed oil (preferred for its cheapness) was rubbed well into the skin, to destroy any putrefactive organisms lying amongst the roots of the hairs ; for any so situated might escape the action of the external antiseptic dressing, and communicate putrefaction to the discharges, and thence to the interior of the wound. The sponges used in the operation were wrung out of a watery solution of the acid (1 to 40), and all the instruments introduced into the wound, together with the fingers of my left hand and the copper wire used for sutures, were treated with the same lotion, some of which was poured into the wound after the introduction of the last stitch, at one of the intervals left for the escape of discharge, to make sure against the chance of any fresh blood which had oozed out during the process of stitching having regurgitated and taken living

germs in with it. The external dressing was a towel saturated with the oily solution, folded as broad as the length of the neck, round which it was wrapped so as to extend freely beyond the wound in all directions, prevented from slipping backward and forward by being stitched to a halter round the head, and to a girth behind the forelegs, while a bandage rolled round it kept it applied accurately to the surface. A sheet of gutta-percha tissue, to prevent contamination of the antiseptic towel from without, and another roller, completed the dressing; and a 'cradle' was placed upon the neck to check lateral movements which might disturb it. I have described these particulars because I am more and more convinced of the necessity for scrupulous attention to details such as the germ theory dictates, in order to attain anything like uniformity of successful results.

A few ounces of the oily solution were poured daily over the towel for the first week, after which the dressings were left untouched for three days, and then entirely removed. The wound was found quite dry and free from tenderness, and the cloth showed only a superficial bloody stain. The stitches being taken out, a drop of pus escaped from the track of the suture next the head; but this was the only appearance of suppuration in the case from first to last, and on the separation of the scab, a few days later, a sound cicatrix was disclosed. A month (thirty days) after the operation the animal, which had continued in perfect health, was killed, and the soft parts of the neck below the spine were removed for examination. On dissection I was struck with the entire absence of inflammatory thickening in the vicinity of the vessel, the cellular tissue being of perfectly normal softness and laxity. On exposing the artery itself, however, I was at first much disappointed to see the ligatures still there to all appearance as large as ever. But had I borne in mind what I had observed in some of my earlier cases of compound fracture treated antiseptically, I should have been prepared to find these threads present in appearance, though absent in reality. It may be well for me to quote from the account I have before given of one of these cases.[1] It was a compound fracture of the leg, produced by direct violence, with a wound of considerable size, and a great deal of extravasation of blood into the limb. In accordance with the practice which I then followed, a piece of lint soaked with undiluted carbolic acid had been placed over the wound, and had formed with the blood a firm crust. 'Nearly three weeks after the accident I was detaching a portion of the adherent crust from the surface of the vascular structure into which the extravasated blood beneath had been converted by the process of organization, when I exposed a little spherical cavity about as big as a pea, containing brown serum, forming a sort

[1] See *Lancet* for March 16, 1867, p. 328 (p. 8 of this volume).

of pocket in the living tissues, which, when scraped with the edge of a knife, bled even at the very margin of the cavity. This appearance showed that the deeper portions of the crust itself had been converted into living tissue. For cavities formed during the process of aggregation, like those with clear liquid contents in a Gruyère cheese, occur in the grumous mass which results from the action of carbolic acid upon blood; and that which I had exposed had evidently been one of these, though its walls were now alive and vascular.' Thus the dead, but nutritious mass, had served as a mould for the formation of new tissue, the growing elements of which had replaced the materials absorbed, so as to constitute a living solid of the same form.

Hence it might have been anticipated that the ligatures of peritoneum and catgut placed on the calf's carotid would, after the expiration of a month,

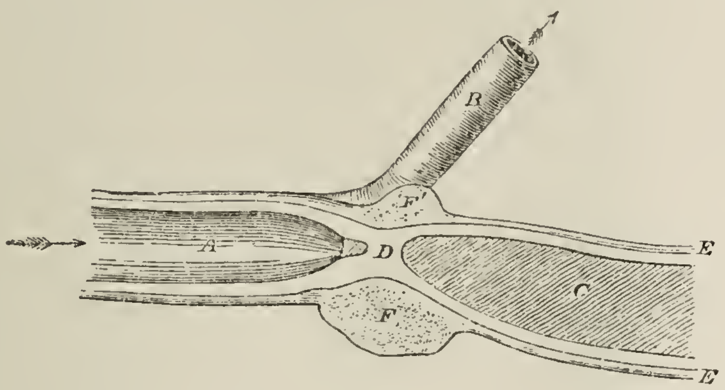


FIG. 2.—The vessel seen in longitudinal section, magnified three diameters. From a camera-lucida sketch. *A*, the artery to the cardiac side of the ligature, kept free from clot by the stream of blood through the branch *B*. *C*, the coagulum filling the artery to the distal side of the ligature, *F*, *F*. *D*, the middle and internal coats, somewhat thickened and blended together within the grasp of the ligature. *E*, the external coat continuous in structure with the organized ligature.

be found transformed into bands of living tissue. Such was, in truth, the case, as was apparent on closer examination. They had, indeed, a deceptive resemblance to their former condition, from the persistence in their substance of the impurities of the original materials, the dark adventitious particles being of mineral nature incapable of absorption, so that they had remained as a sort of tattooing of the new structure. Nevertheless, a marked alteration in colour had taken place, especially in the distal ligature, where the dirty grey of the softened catgut had changed to a dirty pink tint. The two pieces of catgut which had been tied round the vessel at that part had become, as it were, fused together into a single fleshy band, inseparably blended with the external coat of the artery. The knots were nowhere discoverable, and the only indication of the end which had been left long at the time of the operation was the presence of a black speck here and there upon a delicate thread of cellular tissue in connexion with the vessel. The cardiac ligature was in like manner continuous

in structure with the arterial wall. The short ends had disappeared ; but the massive knot was represented by a soft smooth lump, which appeared at first entirely homogeneous, except that it was speckled with dark particles, as before referred to. On section, however, I discovered in the interior of the mass, and lying close to the wall of the artery, a small residual portion of the original knot, of comparatively firm consistence, and with the three-fold twisted character of the cord plainly visible. It was quite distinct from the living tissue that surrounded it, so that it could be readily picked out from its bed with a pair of needles. A slender and irregular remnant of the noose was also found lying in a sort of tubular cavity, extending about half round the vessel.

Thus the process of organization had not yet quite invaded the entire thickness of the foreign solid, and it was a happy circumstance that the thread had been so constructed that the distinction between the old structure and the new could be plainly recognised.

Ample as was the evidence afforded to the naked eye of the organization of these ligatures, it was satisfactory to find it confirmed in the clearest manner by the microscope. A bit of the residue of the peritoneal thread, having been teased out with needles in a drop of water, presented, like a fresh piece of peritoneum, the wavy bundles of parallel fibres characteristic of perfectly developed fibrous tissue. Adhering to the surface of the remnant of the ligature was some soft opaque material, readily washed off with water, consisting of corpuscles of different forms, most of them caudate or fibro-plastic, but some spherical, though not resembling those of pus ; and here and there fragments of the original peritoneal tissue, affected more or less with interstitial cell-development. At a short distance from the remains of the old thread, the fleshy material which had been formed at its expense proved to be a most beautiful example of fibro-plastic structure, the coarse fibres which mainly constituted it being composed of very large elongated cells, often containing several nuclei, and presenting in their course branchings and thickenings of various forms, as represented in the sketch (Fig. 3). Here and there were some fibres more perfectly formed, and also cells of a more rudimentary character. Again, the band which had resulted from the organization of the two fine threads of catgut, which, from the smallness of their bulk, had no doubt vanished early, having had longer time to perfect its structure, was a comparatively well-developed form of fibrous tissue, consisting of coarse fibres rather than of elongated cells, being thus intermediate between the merely fibro-plastic material of more recent growth and the completed texture of the original thread. For it is to be remarked that a piece of catgut exhibits under the microscope abundance of perfect fibrous tissue. A more favourable period for the investigation, with a view to establishing the

nature of the change which ligatures of animal tissue experience under antiseptic management, could hardly have been selected.

Between the parts tied the calibre of the artery was occupied by adherent coagulum, which was for the most part decolourized, and exhibited under the microscope fibro-plastic cells of irregular forms. A similar clot was present between the distal ligature and a small branch that arose about a quarter of an inch beyond it. But between the proximal ligature and the heart the forma-

FIG. 3.—Some of the elements of the fibro-plastic structure of the organized peritoneal ligature at the knot *F*. From a camera-lucida sketch. Magnified 500 diameters.

tion of a coagulum had been entirely prevented by a large vessel taking origin immediately above the part tied, which had thus borne for a month the full brunt of the cardiac impulse. Yet the vessel, so far from showing any sign of giving way, as it would inevitably have done had it been tied in such a situation without antiseptic precautions, appeared to have derived additional strength from the operation. The encircling ring of new tissue incorporated with the arterial wall must have had a corroborative effect ; and within its grasp the inner coats, which seemed to have been but imperfectly ruptured by the soft and substantial ligature, were considerably thickened, and had coalesced so

as to form a strong cul-de-sac, the irregularities of which had been smoothed over by a little fibrinous deposit, which had assumed the characters of a firm fibrous tissue, and presented a free surface undistinguishable from that of the lining membrane of the artery (Fig. 2).

At the situation of the distal ligature the structure of the vessel seemed entirely unaffected. The middle coat was seen in longitudinal section as a pink streak between two white lines, representing the external and internal tunics, neither thicker nor thinner than in neighbouring parts. The catgut threads had been tied too gently to produce rupture of the internal and middle layers, and their presence and the constriction which they occasioned, whatever may have been their effect in the first instance, had left no permanent marks of disturbance; while the fleshy band that had replaced them, though in time it would doubtless have dwindled down to an insignificant filament, was at least a temporary addition to the strength of the artery.

These appearances at the distal ligature are calculated to revive under a new aspect the old question whether it would not be better always to avoid rupture of the internal and middle coats, which could easily be done by using a pretty thick piece of catgut softened by steeping it in a watery solution of carbolic acid. In this way the wall of the vessel would be left from first to last entirely intact. This, however, is probably a matter of indifference. Indeed, judging from the condition of the artery at the cardiac ligature, the injury done to the vessel at the outset by tight tying seems to lead to changes which increase its power of resistance, which was certainly severely tested in the present instance.

It appears, then, that by applying a ligature of animal tissue antiseptically upon an artery, whether tightly or gently, we virtually surround it with a ring of living tissue, and strengthen the vessel where we obstruct it. The surgeon, therefore, may now tie an arterial trunk in its continuity close to a large branch, secure alike against secondary haemorrhage and deep-seated suppuration—provided always that he has so studied the principles of the antiseptic system, and so carefully considered the details of the mode of dressing best adapted to the particular case in hand, that he can feel certain of avoiding putrefaction in the wound. For my own part, I should now, without hesitation, undertake ligature of the innominate, believing that it would prove a very safe procedure.

Catgut, manufactured from the small intestine of the sheep,[1] may be had at a low price, from the thickness of a horsehair upwards. As sold in the shops, however, it is quite unfit for the purposes of the surgeon. For, when moistened with water or with the animal fluids, it becomes not only very soft and weak,

[1] I need hardly remark that catgut is of a totally different nature from so-called silkworm's gut, which is in reality unspun silk. (See also p. 84 of this volume.)

but as slippery as a piece of recent intestine, so that a knot tied upon it yields to the slightest traction. But it is a happy circumstance that a simple process of preparation deprives it of these objectionable qualities. For this purpose, no method which I have yet tried answers better than that which I happened to use first of all for rendering the gut antiseptic—viz. suspending it in a mixture of five parts of some fixed oil (e.g. olive or linseed) with one part of carbolic acid liquefied by adding five per cent. of water to the crystals. Part of the water associated with the acid is disengaged by the oil, producing a very fine emulsion, which effects a remarkable physical change in the animal tissue. At first the gut is rendered swollen, soft, and opaque, though not to so great an extent as if placed in simple water ; but in the course of a few days the opposite change begins to show itself, and the thread becomes gradually firmer and more transparent, till, after the lapse of a few weeks, it is quite free from opacity, and very strong, though supple. If drawn through the fingers, it is no longer slippery, but has a crisp feel like a thread of india-rubber, and a knot tied upon it holds more securely than one on waxed silk. Water, whether cold or at a temperature of 100° Fahr., has now little effect upon the thread, and even putrid serum of blood acting upon it for days at the temperature of the body does not make the knots relax their hold. In this form the gut seems almost a perfect material for the ligature under any circumstances in which it is required.

'Prepared catgut' will, I hope, soon become a well-known article of commerce. But, for the sake of surgeons who may wish to prepare it for themselves, it is necessary to mention, in order to avoid disappointment, that the essence of the process is the action of an emulsion of water and oil upon the animal tissue. The same effect is produced upon the gut, though more slowly, by an emulsion formed by shaking up simple olive oil and water, as by one which contains carbolic acid. On the other hand, an oily solution of carbolic acid without water has no effect upon the gut beyond making it antiseptic, and if water be added only in the small proportion which the acid enables the oil to dissolve, though the gut is rendered supple, and acquires a dark tint from the colouring matter of the oil, it will be found, even after steeping for months in such a solution, that when transferred to water it swells up and becomes soft, opaque, and slippery, as if it had not been subjected to any preparation. How it is that an emulsion produces this remarkable change in the molecular constitution of the tissue I do not profess to understand. I was at first inclined to regard it as a closer aggregation of the particles, brought about by a kind of slow drying of the moistened gut in the oil, as the watery particles precipitate to the bottom of the vessel ; but, not to mention other circumstances opposed

to this view, the oil remains turbid for a very long time, the finer particles of water being extremely slow in precipitating, and if, after the lapse of weeks, a piece of dry unprepared gut is suspended in it, the thread is soon rendered soft and opaque by the very liquid in which gut which has been longer immersed is growing constantly firmer and more transparent. It is necessary that the gut be kept suspended so as not to touch the bottom of the vessel, for any parts dipping into the layer of precipitated water would fail to undergo the change desired. The vessel containing the emulsion should be left undisturbed, for if the water is shaken up with the oil the process is retarded. An elevated temperature of about 100° Fahr. seems for a while to promote the change, but ultimately leaves the gut in an unsatisfactory state compared with that obtained at an ordinary temperature. And conversely some portions of gut which I have prepared lately (February 1870) in a room without a fire, in cold weather, at a temperature of about 46°, were in one week already in a trustworthy condition for surgical purposes. Hence the gut should be prepared in as cool a place as possible. The longer it is kept in the emulsion, the better the gut becomes. I once feared that it might in time grow too rigid for convenience, and possibly brittle also ; but experience shows that this is not the case. When removed from the emulsion it soon dries in the air, but retains a considerable portion of its carbolic acid for several hours, so that no apprehension need be entertained of loss of its antiseptic property from exposure during the performance of an operation. In course of time it loses all the carbolic acid also, but retains permanently its altered molecular condition. If thus kept dry, as may prove the most convenient for the manufacturer on a large scale, it must be steeped thoroughly in some antiseptic lotion before it is used. And for the surgeon the most convenient way will probably be to keep it always in the antiseptic emulsion, so as to be ready for use whenever it is required.

For tying an arterial trunk in its continuity, catgut at least as thick as common purse-silk will be found best. But for ordinary wounds, where, if one ligature happens to break, another can be easily applied, much finer kinds may be employed, and are convenient from their smaller bulk. Several yards of fine gut may be carried in the pocket-case, on a winder contained in a little oil-tight silver capsule which I have had constructed for the purpose, as an appendage to a caustic-holder.

AN ADDRESS ON THE CATGUT LIGATURE

Delivered before the Clinical Society of London, January 28, 1881.

[*Clinical Society's Transactions*, vol. xiv.]

Gentlemen.—In thanking you for the great honour which you have conferred upon me by my election to this chair, I do so with a peculiar feeling of gratitude, because I am well aware that my personal share in the proceedings of the Society has not been such as to entitle me to hope for so great a distinction at your hands. I can only strive to discharge to the best of my ability the important duties which your kindness has imposed.

In considering the choice of a subject for the inaugural address which is expected from your President, I have felt myself precluded from presenting a summary of the labours of the Society in the past, or from tendering advice as to its conduct in the future, and, after consultation with some influential members of the Council, I have decided to bring before you this evening a special subject, which will, I trust, be thought not unworthy of the occasion, inasmuch as, while it is still in an unsettled or transitional state, it is full of interest for every practical surgeon, and at the same time, in some of its aspects, well deserves the attention of the pathologist and the physician—I refer to the catgut ligature. In adopting this course I feel it needful to crave your indulgence; for the subject is a large one, and, in order to do it anything like justice, I shall have to trespass for a considerable time on your attention.

The catgut ligature has in some respects exceeded my original hopes. I feared that its advantages would be limited to wounds in which putrefaction was avoided, and that, if septic suppuration took place in a wound in which it was employed for securing the vessels, the ligatures would, sooner or later, come away like little sloughs. Such, however, has not proved to be the case. Whatever be the progress of the wound, we never see anything of the catgut; so that even surgeons who have not adopted strict antiseptic treatment have been led to employ the new material in ordinary wounds. Under other circumstances, however, the catgut has often led to disappointment. We hear of cases in which the Caesarian section has been performed, and all has gone on well until the knots of the catgut with which the uterine wound was secured have given way, and the patient's death has been the result. Again, in ligature of large arterial trunks in their continuity, several surgeons have met with

bitter disappointment, the case ending in disaster from secondary haemorrhage, or the treatment proving abortive through the channel of the vessel becoming opened up again at the site of the ligature. Hence many surgeons have been induced to return to silk, even though using strict antiseptic treatment—rendering the silk aseptic by steeping it in a suitable lotion, and cutting the ends short. This practice has, however, by no means proved uniformly successful. As an instance of unsatisfactory result, I may mention a case which was recorded by Mr. Clutton in the last volume of our *Transactions*. He tied the external iliac artery with silk under strict antiseptic precautions, and the wound healed within a week ; but, as I learned from a letter which he was good enough to send me at the time, 'six weeks after the operation a little blister formed, and fluid began to escape, forming a small scab, and in three months the loop which had been placed around the artery came away.' Such a result was not at all surprising to me, seeing that what induced me to try the animal ligature was the discovery of a small abscess about the remains of a partially absorbed silk thread which I had applied in the same manner as Mr. Clutton, and, as it so happened, to the same artery.[1] It can hardly be doubted that suppuration proceeding from the immediate seat of the ligature must be a source of danger. As an illustration of the mischief which a ligature of ordinary material may do, I may mention a case of goitre in a young woman on whom I operated on the 28th of January last year. It was of moderate dimensions ; but the effect on the respiration was so considerable that I determined to remove it, following Dr. Patrick Heron Watson's plan of preliminary deligation of the thyroid vessels circumferentially to the tumour. If this be effectually done, the operation is bloodless ; so that, as the laryngoscope applied by Dr. Felix Semon, who had recommended the case to my care, showed that the anterior wall of the trachea was pressed backwards considerably by the growth, I adopted a measure which I believe would in all cases of removal of the thyroid prove advantageous, namely, after the preliminary deligation of the vessels, I divided the tumour in the middle line, so as, in the event of adhesion to the trachea, to be able to remove the two halves of the growth at leisure, dissecting it off from the trachea more or less completely as may be desired, leaving some portions at the adherent parts, and thus avoiding the deadly risk of perforation of the air-passage. But in order that the circumferential ligature of the thyroid vessels may be secure, it is essential that the material employed should be very strong, so that the tissues round about the tumour, including the vessels, may be thoroughly tightened up. I possessed no catgut which I felt was resistant enough to bear the full strength of my hands, and therefore I was compelled to use the hempen

[1] See 'Observations on Ligature of Arteries on the Antiseptic System' (p. 86 of this volume).

ligature—after, of course, carefully rendering it aseptic by means of carbolic lotion. Six of these hempen ligatures were used—three on each side. During the first eight days, everything went on in a typical fashion according to the antiseptic method. There was a merely serous effusion, rapidly diminishing in amount; and we looked to the wound being healed in a few days more. But on the ninth day there was seen to be a little something of purulence mingled with the discharge; and the pus afterwards became thicker, though always in small quantity; a little could be pressed out from each side; and in a month, one of the hempen ligatures made its escape. Six days later, four others of the hempen threads came away altogether unaltered, as may be seen on one of the cards on the table where I have exhibited them. I submitted them to careful examination. They had a sour odour, and, applied to litmus paper, gave an acid reaction, that is to say, the natural alkaline condition of the blood-serum had been changed to acidity by some peculiar species of fermentation. On examining them with the microscope, I found the interstices of the threads of the hemp loaded with a form of organism, to which I believe I happened to be the first to direct attention as to its mode of growth,[1] and to which I gave the name of Granuligera, occurring in groups of two, three, four, and so forth, as distinguished from the chains of ordinary bacteria, and of which one species at least has been since shown by Mr. Cheyne to occur very frequently in cases treated antiseptically, without any interference with aseptic progress. I found that the interstices of the threads of the hemp were loaded with these little micrococci. It so happens that I have had the opportunity, within the last few days, of obtaining a sample of these micrococci, thanks to Mr. Cheyne's kindness. He brought this flask, containing then a pure and perfectly transparent organic infusion, to a case which I had operated on a fortnight before by excision of the ankle. The skin had been unbroken, so that I was able to operate antiseptically, and the case pursued a perfectly typical course. The wounds, which were left gaping at the time of the operation, were filled with blood-clot, which remained unaltered in appearance, though undoubtedly organized by that time, more or less. A little piece of the blood-clot from one of these wounds was introduced with careful antiseptic precautions into the flask of clear fluid, and you see it is now turbid, and there is under the microscope on the table a specimen of the little organism to which the turbidity is due. But though, under ordinary circumstances, these micrococci may be present, as Mr. Cheyne has abundantly shown, and as the excision of the ankle I have just referred to illustrates, without causing any evil, yet there may be circumstances in which they may prove mischievous; and the case of goitre

[1] See *Transactions of the Royal Society of Edinburgh*, vol. xxvii, 1875 (see vol. i, p. 282).

which I have been relating appears to have been one of these. The micrococci, developing for a protracted period in the interstices of the hempen ligature, produced their special fermentation of the serum in its most aggravated form. The acid serum became a cause of irritation; and thus the ligatures, which otherwise, being unirritating in their own substance, might have become encapsuled, and in due time absorbed, became causes of suppuration. One of the six ligatures still remained unaccounted for. In due time we sent the patient home with a small sinus remaining, a little pus always discharging from it; but it was not until the middle of September that the last ligature came away, altogether unaltered. Now, gentlemen, there is no doubt whatever that, if I had had catgut which I could have trusted for the operation, the catgut ligatures would have been disposed of within two or three weeks, and the healing, instead of requiring eight months, would probably have been completed in a fortnight. Here, then, we have an illustration of the great disadvantage which may arise, even under antiseptic treatment, from the use of the ordinary forms of ligature.

Animal ligatures of another kind have been provided by Mr. Barwell, in order to remove these difficulties, namely strips of the mingled yellow elastic and unstriped muscular tissues which constitute the arterial wall, obtained by cutting spirally the aorta of one of the larger animals. But, though fully admitting the efficiency of these ligatures in his hands, I am given to understand that their form and size render them by no means very convenient, and, independently of this, I cannot but feel that it is unsatisfactory, if it can be avoided, to have a special material for this particular object, and that it would be better, if possible, to have the catgut in a thoroughly reliable condition. Catgut, of which I have samples here, is to be had all over the world in abundance. It is beautifully strong and smooth; it is made of various sizes suitable for all surgical requirements, and is extremely cheap. Wholesale, it is sold at 12*s*. per gross, that is to say, one penny per hank. But, as it comes from the maker, it is entirely unfit for the purposes of the surgeon. However beautiful it is in the dry state, it becomes soft and pulpy soon after it has been placed in blood-serum. In one of these glasses is a piece of unprepared catgut which was placed in warm serum this morning, obtained from the blood of a cow, and within half an hour it was in the condition in which it is at the present time—swollen, soft, and pulpy. A knot tied upon it in its present state would hold as little or scarcely better than would one on a piece of the slippery intestine from which the catgut is derived. It is essential, in order to fit the catgut for the purposes of the surgeon, that it be altered in its physical constitution so as to be no longer liable to this softening effect by the serum of the blood. It is a remarkable circumstance that the blood-serum softens catgut even more than water does.

It might have been expected, *a priori*, that a solution of a colloidal substance like albumen would have been much less disposed than water to permeate and soften an animal tissue like catgut ; but it is otherwise, and therefore we cannot test the trustworthiness of catgut by steeping it in warm water, as I formerly used to do. In order to be sure that a given specimen will answer the purpose in so far as the knot is concerned, that it shall not slip, it is needful that we should steep it in blood-serum, a somewhat troublesome process, as it involves sending to a slaughter-house for blood.

The method of preparing catgut which I published long ago answers the purpose very well, even for the ligature of arteries in their continuity, provided certain conditions be complied with ; such, at least, is my own experience. This, indeed, has not been very extensive, but it has been sufficient to deserve consideration. I have tied altogether nine large arteries in their continuity with prepared catgut. Of these, one was a case of ligature of the carotid, in a young woman, aged twenty-two, with a pulsating tumour below the angle of the jaw, in the situation of a carotid aneurysm and with all the symptoms of that disease. The application of the ligature reduced to a certain degree the pulsation and the dimensions, but the further cure which we hoped for did not take place. She left the hospital with a pulsating tumour ; and I heard only yesterday from the medical man under whose care she is in Scotland, that this tumour, for which I tied the carotid artery in 1874, still exists as a pulsating swelling, if anything, rather on the increase. But though, as regards the cure of the disease, the ligature was unsatisfactory, nothing could be more beautiful in its effect as respects the healing of the wound without suppuration, and the permanent obstruction of the vessel at the seat of ligature.

A case of traumatic arterio-venous aneurysm of the temporal artery, in a young man lately under my care in King's College Hospital, may be mentioned in this category, partly because the greatly dilated condition which the naturally small artery had assumed brought it up towards the dimensions of a large trunk, and partly because the concurrent ligature of the largely dilated veins would, without antiseptic means, have been justly regarded as of considerable danger. The others were all cases of ligature of the femoral. Six were popliteal aneurysms. Four of these presented nothing deserving of special remark. One was a diffuse aneurysm, extending up to the junction of the lower and middle thirds of the thigh, and the other was an enormous diffuse aneurysm reaching up to Poupart's ligament, so that it was necessary for me to tie the femoral artery about the situation of the ordinary origin of the profunda, and even there my incision opened into the aneurysmal clots.

The last case that remains to be mentioned was a large arterio-venous

aneurysm of the upper part of the femoral, of idiopathic origin. This case was of such special interest that I hope, on a future occasion, to make it the subject of a paper before this Society. In all these cases, except two, catgut prepared by the old method was employed, and in all these nine cases the result was satisfactory, and recovery perfect, except as regards the poor young woman who has still the pulsating tumour in her neck

As to the mode of applying the ligature, I have always used a single reef-knot with short-cut ends, tying it sufficiently tightly to cause the giving way of the internal and middle coats. This latter point is not, perhaps, essential, as I long ago surmised,[1] and as Mr. Barwell's experience with his aortic bands appears to indicate. But if, as is the case with catgut, the form of the ligature admits of it, the injury done to the deeper tunics is, I believe, advantageous, by leading to a salutary corroborative process of repair.

Why, it may naturally be asked, has my own experience been more satisfactory with the catgut ligature than that of many other surgeons? There are, I believe, two reasons for this. One is that I have never ventured to tie an artery of considerable size in its continuity without having taken pains to ascertain that the catgut was of thoroughly reliable material; and the other reason is that I have adopted strict antiseptic means of treatment, not only during the earlier stages of the case, but to the last. So long as any part of the wound remains unhealed, antiseptic treatment of the strictest kind ought, I believe, to be employed. Even though the sore may seem to be superficial, there may still exist a sinus leading down to the site of the ligature; and if ordinary treatment, as distinguished from antiseptic, be employed, down this sinus the septic process may advance and invade the ligature, and lead at last to disaster from haemorrhage. I know that this has actually taken place.

But although the catgut prepared after the old method answers very well if it be in proper condition, there is this great objection to that method: that it requires a long time in order to produce the requisite quality. At least two months are needed to make the ligature at all trustworthy. It is better at the end of six months, and still better at the end of a year. I possess catgut prepared in this way twelve years old. I have brought here a sample of such catgut, which has been steeping in warm blood-serum since this morning, and it will be seen that it remains translucent, and is comparatively firm, instead of being opaque and soft, like the unprepared catgut in the same serum.

Now, the length of time that the present method requires is a very serious objection. It places the surgeon who has not prepared the catgut for himself, and kept it for a long time, at the mercy of the person who supplies it; and

[1] Cf. p. 98 of this volume.

the person who supplies it, not being aware of the enormous importance of the question of time, if he happens to run out of that which has been long prepared, will sell what has been only a short time in the preparing liquid, and is, in consequence, altogether untrustworthy. A case illustrating this point occurred last year in my practice at King's College Hospital. A patient was admitted who had met with a severe wound on the ulnar side of the forearm, at the anterior aspect. The ulnar artery had been divided. This had been secured by my house surgeon, who had also tied with catgut the corresponding ends of the various tendons that had been severed. But, when I saw the patient next day, I found that he could not feel with his little finger and the adjacent side of the ring finger, and, therefore, it was evident that his ulnar nerve also had been divided, and my house surgeon had not thought of attending to the ulnar nerve. I therefore cut the stitches in the skin, and proceeded to explore the deeper parts of the wound, in order to find the ends of the divided nerve, and tie them also together with catgut ; and I found that all the catgut sutures with which the ends of the several tendons had been tied together were lying absolutely loose ; the knots had slipped within the twenty-four hours ; and yet this catgut had been supplied by one of our ordinary instrument-makers. He had sent us what had not been sufficiently long prepared. I took care to use proper catgut for the ulnar nerve ; and the patient left the hospital with restored sensation in the fingers. The length of time that it requires is, therefore, an exceedingly serious objection to the present method of preparation ; and one great object which I have had in view, in a series of experiments on this subject, has been to devise a means, if possible, of preparation within a short time. These experiments—it may seem almost ludicrous to say so—have occupied two years of my leisure in the past, some time ago ; and, after being interrupted by an accidental circumstance, have been continued in a more desultory manner since ; but at length I feel myself justified in bringing before you a new mode of preparation, by which the catgut may in a short period be brought into a perfectly reliable condition.

But before I allude to these experiments, which I must endeavour to do in a short compass—I should weary you if I were to bring a large proportion of my facts before you, though I may say, out of the hundreds of experiments I have performed on the subject, I have never performed one which has not added something to my knowledge of it—before referring to these experiments, I wish to say a few words as to what catgut is. Catgut, as you are all doubtless aware, is prepared from the small intestine of the sheep. The gut is treated in what seems an exceedingly rude manner for so delicate a structure. It is scraped with some blunt instrument, such as the back of a knife, over a board ;

and by this means, as the people express it, the dirt is scraped out. That which these persons call the dirt is the exquisite and complicated structure of the intestinal mucous membrane. But while the mucous membrane is scraped out from within, there is also scraped off from without, the circular coat of muscular fibres. The result comes to be that the intestine is converted into a comparatively unsubstantial material, consisting of two parts, or bands, one more slender than the other. When the intestine is stripped from the mesentery by the butcher, the peritoneal covering of the gut shrinks into a narrow strip, and this, with some longitudinal fibres, constitutes the more slender of the two parts to which the intestine is reduced by the process of scraping. The other part is the essential material from which the catgut is prepared, and this is neither more nor less than the submucous cellular coat of the intestine. When I first visited a catgut manufactory I was astonished to find that, after this scraping process, the intestine could be blown up still as a continuous tube, as you see can be done with this specimen, which has been treated in the manner I have described. This translucent membranous tube is a beautiful anatomical preparation of the submucous cellular tissue, though made in so rude a fashion. This coat of the intestine, which in the sheep has such extraordinary toughness, is the material out of which the catgut is prepared. For what the manufacturer terms the ' ones '—the thicker form of ordinary catgut—all that is done is to twist the entire tube by means of a wheel, like a rope in a rope-walk, up to a considerable degree of tightness, and then allow it to dry. It is afterwards exposed to the fumes of burning sulphur, and for some more special purposes it is bleached by the action of potash. But the essential thing is the twisting and drying. It can be manufactured without sulphur, as well as without potash. Some specimens which I have here were made by means of water only, without the use of any other ingredient. This exceedingly beautiful material, as fine and smooth as a horsehair, is nothing but the animal tissue twisted and dried. For the finer kinds the submucous coat is split up by means of razor blades, more or less numerous, according to the degree of splitting required, connected with a conical piece of wood which is pushed along the tube.

Such, then, is the material with which we have to deal. The first of the more recent experiments which I performed with reference to it was made with the view of ascertaining, if possible, what part the water played in the ingredients used for the preparation by our old method. If I steep unprepared catgut in a mixture of dry carbolic acid and oil, however long it be so steeped, although it will be of course abundantly aseptic, it remains utterly unfit for the purposes of the surgeon ; a knot upon it would still slip in a wound. But if, instead of using carbolic acid in the crystalline state, we use carbolic acid which has been

liquefied by the addition of a little water, we get in course of time a properly prepared catgut. I wished to ascertain how much water was required. The carbolic acid would enable oil to dissolve a certain amount of water; would that amount of water be sufficient which carbolic acid enables oil to dissolve? Accordingly, I prepared jars of carbolic oil, some containing the full amount of water we had used hitherto, some a smaller quantity, and some none at all, and placed in them portions of the same hank of catgut. In due time I proceeded to examine the result, by taking portions of gut and putting them into warm water and leaving them for a while, in order to ascertain how the knots would hold. To my great surprise, I found that which had been steeping in the carbolic acid and oil without any water just as good as that which was in the carbolic acid and oil with the water. This was contrary to distinct previous experience. Reflecting on the matter, I saw that the only possible explanation was that the catgut was already, so to speak, prepared before I put it in the liquid. Now it so happened that the catgut I had used was several years old; and it turned out that mere age of the catgut prepares it; that in proportion to its age it is rendered less liable to be softened by water or by blood-serum and a knot tied upon it will hold better. And thus I had for the first time, I believe, scientific evidence of the truth of what is popularly spoken of as the 'seasoning' of various articles made of animal products. I asked a person who sold violin strings if there was any result from keeping the strings a long time. He replied that the only result he knew of was that they would probably get rotten. But it so happened just about that time there came an old fiddler to amuse the patients in the Royal Infirmary, Edinburgh, at Christmas time. The weather was wet, and he said that his fiddle would not work properly because the fiddle-strings were not properly seasoned. So he was aware that fiddle-strings, which of course are catgut, are liable to seasoning, and require it. The knowledge of this effect of the mere lapse of time was very important, because it enabled me to explain the success that I had had in my earlier experience with catgut before I knew at all the proper mode of preparing it. I look back with horror at some of my early procedures with catgut. I have operated, for example, on an irreducible ventral hernia, opened the sac, divided the adhesion, returned the protruding intestines, stitched up the mouth of the sac with catgut, and then applied stitches at considerable intervals in the skin. All went perfectly well; but the mode of preparation that I then used, if I had worked with catgut recently made, must have led, in such a case, to utter disaster; the knots must have slipped in a few hours, and the intestines must have been protruded through the wound.

I need hardly say this mode of preparation, interesting though it is, would

not be satisfactory ; it would only have, in a more aggravated form, the inconvenience of the extremely long period which our old method demands. Besides that, it by no means fulfils all the conditions that are required for a perfectly satisfactory state of the catgut for surgical purposes. These conditions I will now mention. In the first place, I have spoken of a short period of preparation. This is very desirable. Then it is essential that the catgut should have proper strength, so as to bear any reasonable strain that the human hands can put upon it, in the thicker forms, as when used, for instance, in such cases as the circumferential ligature of the thyroid vessels in the removal of a goitre, or for securing the pedicle in ovariotomy. And it is not sufficient that it should be strong to start with ; it is easy to get catgut strong in the dry state ; it is necessary that it should be strong after steeping in blood-serum for a while. Take, for example, the case of tumour of the thyroid. I employed six ligatures, and in a former case, where the tumour was larger, I thought it prudent to pass as many as eight, so as to subdivide more the mass that had to be tied ; but it is not convenient to tie each of these ligatures as soon as it is passed, and the process of passing takes a considerable time. Now it would be a very sad thing if the residence of the catgut among the tissues soaked with serum for a few minutes, or even a quarter of an hour, should render it so soft that it should give way when we put the strain of the hands upon it. That, then, is another essential point, if the material is to be useful for all the purposes for which it is desired. Then, again, it is necessary that a knot tied upon it should hold with absolute security, not merely in the first instance, but after soaking for an unlimited time in blood-serum. It is further needful that it should not be too rigid ; for, as we shall see immediately, it is possible for catgut to be over-prepared ; in which case it may remain almost like a piece of wire among the tissues, and ultimately, perhaps, come away by suppuration in consequence of the mechanical irritation which it produces. But while the animal juices must be able to soften it sufficiently to render it mechanically unirritating, yet, on the other hand, it will not do for it to be too rapidly disposed of by absorption. If it is to do duty for the ligature of an artery in its continuity in the immediate vicinity of some large branch, it must remain for a considerable time of good strength, unabsorbed ; and, when it is at length absorbed, it is desirable that it should be removed in such a manner that, while it is reduced in thickness, it shall still, as long as any of it remains, retain its tenacity.

Now, these are a series of conditions which, I assure you, it is not easy to fulfil completely. I have in various experiments complied with some of them easily enough, but failed in others. Sometimes I have succeeded with all but

one, and one has baffled me. I have tried various materials, as you will naturally suppose. One substance that suggested itself was tannic acid, so as to convert the fibrous tissue of the catgut into leather. I succeeded well enough in some respects with tannic acid applied in different ways, but in one respect I did not succeed. I have not obtained by means of tannic acid a kind of catgut that is not too speedily absorbed. Even a piece of kid-leather, cut into a suitable shape for sutures, and rendered aseptic, became too rapidly absorbed.

Chromic acid was another agent which I very naturally tried on account of its well-known effect in hardening tissues. Chromic acid alone does not work very well; but I found that the addition of some other substances to it aided its action very greatly. By adding, for instance, to the watery solution a little glycerine, thus producing a reducing action on the chromic acid, we get a different sort of liquid, which acts much more energetically on the catgut. I was highly delighted with the results of the action of this mixture of chromic acid and glycerine; and just at this time (June 1876), it happened that Mr. Oliver Pemberton, of Birmingham, applied to me for a piece of catgut, for the purpose of ligaturing the external iliac artery in a remarkable case of three aneurysms in one limb—two in the femoral artery, and one in the popliteal. I thought I could not do better than send him a piece of my recently prepared chromic catgut. I did so; and a month afterwards he wrote to me, saying that nothing could be more satisfactory than the result. He had operated antiseptically; the wound had united by first intention; and, so far as the case could go well, all had gone well. There was, indeed, gangrene of the lower part of the leg, which Mr. Pemberton had predicted would occur in consequence of the existence of four successive obstructions in the course of the arterial channel; viz. the ligature and three solid aneurysms. But the case, under proper management, was doing well. Four weeks later, however, Mr. Pemberton wrote to me again, telling me that, soon after his last report, the patient had begun to show signs of suppuration about the seat of the wound. After a while the abscess opened in the cicatrix, and one day the ligature which he had placed on the artery was found lying unaltered on the granulations.[1] It is now on one of the cards before you—an over-prepared ligature, which had come away, rigid and wire-like, making its way out, as a piece of glass might have done, by mechanical irritation. This opened my eyes for the first time to the possibility of having catgut over-prepared. This over-preparation by means of chromic acid is, I understand, to be found illustrated in a large German school at the present time. I have been told by an American physician, who has lately been in London after spending some time at that school, that the catgut ligatures come

[1] For an account of this case by Mr. Pemberton, see *Lancet*, August 4, 1877.

away from all wounds to which they are applied in that clinique. They count the ligatures as they put them on, and invariably see them all before the case is done with. The catgut has been over-prepared.

It is by means of chromic acid, however, that I have at length arrived at a result which appears to satisfy all our conditions. But, before speaking of the new method, I wish to say a few words more with regard to the old. To what is it that it owes its virtue ? In this bottle is some catgut which has been nearly ten months in our old preparing liquid—namely, one part of carbolic acid which has been liquefied by means of water, to five parts of olive oil. In this other vessel again we have catgut which has been the same length of time in a solution of carbolic acid in water. Water will only take up about one-twentieth part of its weight of carbolic acid ; but the effect produced upon the catgut by the watery solution is very much greater than that brought about by the four times stronger oily solution. In the former case, as you can see, the catgut is almost black, a sort of purple black ; while the other is comparatively pale, very little altered from its original colour. This circumstance shows two things. In the first place the effect of the watery solution of carbolic acid upon the catgut explains the efficacy of the water in our old method. It is the watery solution of carbolic acid in the liquid of the old method that is the effective agent. But in the second place we see that, when the watery solution is mixed with oil, the fact that it is so mixed limits and checks its operation. If catgut is kept in the watery solution only, there seems to be no limit to the degree of continuous preparation of the gut—so that it becomes more and more dark in colour, and more and more difficult of absorption by the tissues. It is otherwise when the watery solution is blended with the oil. Though the process does go on for many months, there is a time when it comes to a standstill. You need not fear that catgut prepared by the old plan is ever over-prepared. There is a specimen on the table, which, at the end of twelve years, is as limp, after steeping for a while in blood-serum, as it would have been at the end of a single year. Therefore, we possess in the carbolic oil a means of checking any mode of preparation that we may adopt, keeping it from that time forward not materially further prepared ; while at the same time the large proportion of the carbolic acid to the oil (1 to 5) ensures the catgut being maintained perfectly aseptic.

The method of preparation which I have now the honour to bring before you is the following. I dissolve one part of chromic acid in 4,000 parts of distilled water, and add to the solution 200 parts of pure carbolic acid, or absolute phenol. In other words, I use a 1 to 20 watery solution of carbolic acid ; only that the carbolic acid is dissolved, not in pure water, but in an exceedingly

dilute solution of chromic acid. But minute as is the quantity of the chromic acid, it exerts, when in conjunction with carbolic acid, a most powerful influence upon the gut. The first effect of the addition of the carbolic acid to the chromic solution is to change its pale yellow colour to a rich golden tint. But if the liquid is allowed to stand without the introduction of the catgut, it changes in the course of a few hours to a dingy reddish-brown in consequence of some mutual reaction of the two acids, and a certain amount of grey precipitate is formed. If, however, catgut about equal in weight to the carbolic acid is added as soon as the ingredients are mixed, the liquid retains its brightness, and the only change observed is a gradual diminution of the depth of the yellow colour; the precipitate, if it still occurs, taking place into the substance of the catgut. As soon, therefore, as the preparing liquid has been made, catgut equal in weight to the phenol is introduced into it. If you have too large a proportion of catgut, it will not be sufficiently prepared; if you have too small a quantity, it may run the risk of being over-prepared.[1] At the end of forty-eight hours the chromic element of the liquid has nearly spent itself, and the process of preparation is complete. The catgut is then taken out of the solution and dried, and, when dry, placed in 1 to 5 carbolic oil; it is then fit for use. I have here a sample of catgut prepared by this method. Although it has been steeped in warm blood-serum since this morning at eleven o'clock, it is still translucent and firm without being rigid, and a reef-knot tied upon it holds with the most perfect security.

The strength of the catgut depends upon different circumstances. In the first place, sheep differ as to the strength of their intestines; and the catgut-maker, if he understands his business, will insist upon having his raw material of a proper kind. In the next place, the intestines must not be allowed to putrefy—they must be used when quite fresh. For these things you must, of course, rely upon the maker of the catgut. In the next place, the preparing liquid causes a certain amount of softening of the catgut, and if it is introduced in loose hanks, this will tend to produce a little uncoiling of the twisted cord, and a still greater degree of uncoiling will take place during drying. It is of very great importance that this should not occur, because it involves weakening of the thread, and that in different degrees in different parts; and this may lead to the gut giving way when you subject it to a strain. The catgut, then, should be prepared on the stretch both when it is put to soak and when it is put to dry.

I need not enter into the mode in which this can be done by the manufacturer. I may only say this, that the surgeon who wishes to prepare it himself

[1] A moderate excess of the liquid, not exceeding twice the prescribed amount, does not produce any serious degree of over-preparation.

may do it in different ways. For instance, he may take two large test-tubes, one a little larger than the other, and he may wind the catgut on the smaller tube, fixing one end by sealing-wax, winding it round, then bringing it up again, and fixing the other end also with sealing wax at a higher level than the liquid will reach, putting sufficient liquid into the larger test-tube, and introducing the smaller test-tube with the catgut wound round it, and containing a little shot or other heavy material to keep it down in the liquid. After forty-eight hours he takes out the smaller test-tube, and leaves it till the catgut is completely dry. I merely mention this as an illustration, and also as furnishing a hint to some surgeons in private practice who may desire to prepare the catgut themselves. Or a couple of gallipots, one larger than the other, will do just as well. But, as I have already said, the principal uncoiling takes place during drying ; and for all ordinary purposes a sufficiently good article is got by putting the catgut loose into the liquid, and making it dry on the stretch, by tying the ends of each hank to two fixed points in a room.

In the dry state, catgut prepared by this method is as strong as need be. As to strength in the condition after steeping in blood-serum, I confess it is only this very day that I have obtained evidence that catgut thus prepared is really all that we can desire in that respect. The catgut of the hank from which this specimen was taken measured in the dry state $2\frac{2}{3}$-hundredths of an inch in diameter, and broke at 13 lb. 6 oz. I have found by experiment that 10 lb. is the utmost strain that my arms are able to put upon a cord. Thirteen pounds six ounces, then, is amply sufficient ; while, at the same time, the catgut is not at all too large for going into the eye of an aneurysm-needle. Having obtained, the other day, some fresh blood of a cow from the slaughter-house, I took some of the serum to-day, and put two pieces of this same hank of catgut in the serum, and placed it in a stoppered bottle in a warm box at a temperature of 98° Fahr. After more than half an hour I tested the breaking strain (I must not stop to explain how that is done[1]), and I found that the breaking strain of the same catgut which in the dry state had broken at 13 lb. 6 oz. was 11 lb. 4 oz. ; that is, though suppled by the serum, it had only lost in

[1] The mode of proceeding was as follows. A piece of steel, of horseshoe form, is suspended by a ring on the middle of its convexity, so that the horns of the horseshoe are dependent ; these horns being perforated for the reception of a cylindrical bolt of steel, which thus lies horizontally, and can be removed at pleasure. A piece of the catgut having been tied in a double reef-knot, the bolt is partially withdrawn, and is readjusted after the noose of the catgut has been slipped over it. Into the lower part of the catgut-ring thus suspended is passed the upper end of a pot-hook, to the lower part of which are attached weights approaching what the gut is likely to bear, and also an empty bag, into which shot is poured till the cord gives way. The shot is weighed ; and the result, added to the other weights, gives double the breaking strain of the gut ; for, as the cylindrical bolt works with perfect smoothness in its bed, it adjusts itself so as to prevent inequality of strain in the two sides of the catgut-ring, which thus take an exactly equal share in sustaining the weight.

strength two pounds out of thirteen. I think that is really all that can be desired.

[A few days after the delivery of this address I made some experiments regarding the strength of the new gut after longer periods of immersion, using the serum which I had before employed for the purpose, and which, being derived from blood taken from a cow with antiseptic precautions, remained still perfectly sweet. I first tried the specimen of gut twelve years old, prepared by the old method, a portion of which I exhibited at the meeting steeped in serum. It is comparatively slender gut, having little more than half the thickness of the chromic gut with which I before experimented, the average diameter being $1\frac{2}{3}$-hundredths of an inch. Two trials of it in the dry state gave 5 lb. 9 oz. as the average breaking strain ; and two other pieces, after steeping half an hour in the warm serum, broke at 3 lb. 14 oz. In other words, this especially well-seasoned sample of what the old method could provide was deprived by warm serum of about one-third of its strength in half an hour. I next tested a piece of gut prepared three months ago by the new method, similar in thickness to the other, viz. having an average diameter of $1\frac{2}{3}$-hundredths of an inch. Four trials with it in the dry state gave an average breaking strain of 6 lb. 15 oz. I then placed in the warm serum three other pieces of the same hank, after measuring their diameters. One of these pieces, with diameter $1\frac{2}{3}$-hundredths of an inch, tested after it had been one hour in the serum, broke at a strain of 5 lb. 13 oz. Another piece, which when dry measured decidedly less in diameter than the first, was tried after being fourteen hours and a half in the serum, when it also broke at 5 lb. 13 oz. A third piece, just $1\frac{2}{3}$-hundredths of an inch in diameter when dry, was left in the warm serum for twenty-four hours, at the end of which time it showed a breaking strain of 5 lb. $10\frac{1}{2}$ oz. Thus the new gut continued as strong, or nearly so, at the end of a day in the serum as it had been after the lapse of an hour, and lost in the serum only about one-seventh of its full strength in the dry state, a result corresponding very closely with that obtained in the former experiment with the thicker chromic gut after forty minutes' immersion. At the same time, the new gut being considerably stronger to start with than that prepared by the old method, its strength, after steeping for twenty-four hours in warm serum, was greater than that of the old kind in the dry state.]

The only remaining condition to be considered regarding the new catgut, is its suitable behaviour among the tissues. Before describing this, I must say a few words regarding the manner in which catgut is absorbed. It has been said of late by various persons that the catgut is dissolved by the serum. I must confess that this is entirely contrary to my own experience. I have already

said that, in order to test the quality of catgut, you must have it steeped in blood-serum. I have tested in this manner catgut prepared in various ways. The serum has sometimes been putrid, sometimes it had no smell at all, and sometimes it had a little odour. The serum has been kept about the temperature of the body, but I have never seen the slightest indication of any chemical solution of the catgut. Then, again, as to the behaviour of the catgut in the body: suppose we use it as a stitch, if the catgut were disposed of as a matter of chemical solution, we should expect that, when it is employed as a suture and a piece of our protective is put over it, which is always kept moist with

Fig. 1.—In this woodcut, the suture referred to is represented magnified five diameters. Its actual thickness was one-fiftieth of an inch. The part between *a* and *b* is that which had been among the tissues.

serum perpetually oozing from the wound, the outer parts of the stitch, the parts outside the skin, as well as the parts among the tissues, would show signs of diminution. It is never so. The diminution is always absolutely limited to the parts within the tissues. It is still more striking, as was suggested to me by Mr. Cheyne, to consider the case of catgut used as a drain. There its very function is to drain out the serum, and it is perpetually washed with it. You might suppose that a stitch might perhaps become a little dry; but here there can be no mistake; the serum from the wound is perpetually flowing over the gut, yet, as in the case of the suture, we find the diminution of the catgut is absolutely limited to the part within the tissues. This seems to me sufficient evidence that it is not a question of mere chemical solution of the catgut, but of disposal of the catgut in some way or other by the living textures.

Now, if we examine catgut in the process of diminution in the living body, we find that it may be affected in one of two ways. If it has not been properly prepared, the substance of the catgut becomes converted, in the course of a very few days, into a soft pultaceous mass, which, when we examine it by a microscope, we see consists of remains of the old cellular tissue of the submucous coat, with the interstices among the fibres filled with cells of new formation. The catgut tissue is infiltrated with young growing cells, and it is obvious it is this infiltration which is the cause of the softening. But, on the other hand, if the catgut is properly prepared, instead of being infiltrated by the cells of new formation, it is only superficially eroded. In this stitch (Fig. 1) of catgut prepared by the new method, removed from a wound thirteen days after its introduction, you have a good example of this important fact. You will see that, at the part which was among the tissues, there remains a very slender residue of the catgut, all the rest having gone ; but that slender residue was pretty tough, and remained translucent, showing not even a superficial infiltration ; in short, having exactly the characters that we desire for catgut for the ligature of an artery in its continuity, namely, that it shall not disappear too rapidly, and that till the last, even though reduced in dimensions, it shall retain some degree of its original firmness and tenacity. We know that antiseptic treatment has shown that a piece of dead bone may be absorbed, provided it be not putrid : the granulations that overlap it superficially may, so to speak, erode it. It is not necessary for us now to consider how that is effected ; but certainly, in some way or other, the granulations do what mere steeping in serum, whether putrid or non-putrid, never would do. Never, I believe, would the bone be dissolved by the serum ; and just as a non-putrid sequestrum is served by the tissues, so is a well-prepared specimen of catgut ; it is superficially eroded. I have here a stitch that I removed to-day from a wound made ten days ago—a wound made for stretching the anterior crural nerve, which, as well as the sciatic, was subjected to that treatment, in an aggravated case of sciatica. You may see that, as yet, it shows no signs of erosion. We know by experience that, if it were left three or four more days, we should probably find it eroded, as the former specimen indicates ; but until nearly a fortnight has elapsed erosion does not begin. It then proceeds gradually, and, therefore, the thicker the catgut the longer is the time required for its complete removal. We may fairly consider that from a fortnight to three weeks is long enough for the persistence of a ligature upon an artery in its continuity. [Three days later I removed two remaining stitches in the case last referred to, and found both of them slightly eroded superficially.]

I have brought with me this evening a preparation of the carotid artery

of the calf in which I first established the fact of the substitution of new living tissue for the dead old tissue of the catgut.[1] If any gentleman will examine the specimen after the meeting, he will see the ligatures of new formation incorporated with the external cellular coat of the artery. I have been strangely misunderstood as having intended to convey the idea that the catgut, when it becomes organized, comes to life again. Gentlemen, such an absurd notion certainly never entered into my head; any more than, when I have spoken of the organization of a blood-clot, I have meant by that expression to convey the idea that the blood-clot becomes organized by its own inherent virtue. I found the term 'organization' ready to my hand; it was not a word of my invention. It had been used with reference to lymph. Now, pathologists, in speaking of lymph as becoming organized, did not, I suspect, mean by that expression to imply that it was the lymph-substance that had the power of self-organization, as distinguished from any influence that surrounding tissues might exert upon it. So in the same way the expression 'vascularization of lymph' was used when it was universally believed by pathologists that the new blood-vessels were formed only as loops from pre-existing blood-vessels. Nowadays a different view may be taken, but the term 'vascularization of lymph' was employed without any notion that the lymph itself created the blood-vessels. And so when I spoke of the organization of the blood-clot or of catgut I never meant to convey the idea that the one or the other did the work itself. As to the blood-clot, we know that if it remains free from putrefaction among the tissues, it speedily becomes infiltrated with cells of new formation. Whether the white corpuscles originally present in the clot take any part in the formation of these new cells is a question now under discussion, and one, I conceive, not at all prejudiced by the use of the term 'organization of the blood-clot'. With regard to catgut, I think, if gentlemen would refer to my original paper in the *Lancet*,[2] they would see that I stated very explicitly that new tissue forms at the expense of the old, that the old tissue is absorbed by the new, and that as the old is absorbed, new is put down in its place.

In conclusion, gentlemen, I venture to recommend the new chromic catgut as in all respects deserving of your confidence, and at the same time to thank you sincerely for the patient attention with which you have listened to this address.

[1] See p. 5 of this volume. [2] Ibid.

NOTE ON THE PREPARATION OF CATGUT FOR SURGICAL PURPOSES

[*British Medical Journal*, 1908, vol. i, p. 125.]

CATGUT used for ligatures or sutures in surgery should fulfil various conditions. It should, after soaking in water or blood-serum, be strong enough to bear any strain to which it may be subjected, and should hold perfectly when tied in a reef-knot. It must not be so rigid as it lies among the tissues as to have any chance of working its way out by mechanical irritation. Nor should it be too quickly absorbed, but should be consumed so slowly by the cells of the new tissue that grows at its expense that, in case of the ligature of an arterial trunk in its continuity, it may serve sufficiently long as a support for the substitute living thread in its embryonic condition. At the same time, it is essential that the catgut be securely aseptic when applied.

Of the various substances which I have tried for the preparation of catgut, that which has, with one exception, most nearly approached the ideal is sulphate of chromium. The one exception is secure asepsis of the gut substance, this salt being utterly untrustworthy as a germicide ; this defect is easily remedied by the addition of a little corrosive sublimate, the powerful germicidal action of which is not prevented by the chromium sulphate.

I was at one time discouraged from using chromium sulphate by finding that it varied extremely in quality according to the manufacturer who supplied it. Thus one sample got from a well-known firm proved quite insoluble in water.[1] But a perfectly satisfactory result was obtained by adding solution of sulphurous acid (*Pharm. Brit.*) to solution of chromic acid until the rich orange-brown of the latter has passed through grass-green to the pure blue of chromium sulphate. When this has occurred no more should be added, since free sulphurous acid produces a precipitate with bichloride of mercury, and would thus, in proportion to its amount, withdraw the germicide from solution when the two liquids are mixed. In order to make quite sure that no free sulphurous acid is present, it is well to keep a few drops of the chromic acid liquid in reserve, and add them when the blue colour has appeared, so as to restore the green tint.

[1] I learn from Messrs. Morson (of Elm Street, Gray's Inn Road), who have devoted a great deal of attention to this salt, that its most suitable form requires very great care in its preparation in order to avoid variation in its composition, and also that it is extremely hygroscopic, so that, unless it is very carefully preserved, water in variable amount becomes associated with it, another cause of uncertainty in its composition.

Another point that requires attention arises from the fact that the *P. B.* solution of sulphurous acid, as obtained from the chemist, is generally somewhat deficient in the amount of SO_2, in consequence of loss by volatilization. Hence it is necessary to use a smaller quantity of water for dissolving the chromic acid than would otherwise be used; and when the proper tint has been got, add enough distilled water to bring the liquid to the requisite measure.

The following directions for preparing what is known as chromic (or sometimes sulpho-chromic) catgut in accordance with the above conditions were given to manufacturing chemists in 1894, but have never yet been published:—

'The preparing liquid must be twenty times the weight of the catgut. So for 40 grains of catgut 800 grains of preparing liquid are required. It is made by mixing two liquids—namely, the chromium sulphate liquid and the sublimate liquid.

'The sublimate liquid is:—

Corrosive sublimate	2 grains
Distilled water	320 ,,

'The sublimate may be dissolved by heat, but the solution must be used cold.

'The chromium sulphate liquid is prepared thus:—

Chromic acid	4 grains
Distilled water	240 ,,

'Add to this as much sulphurous acid (*P.B.* solution) as gives a green colour. If more is added the colour becomes blue, which shows that rather too much sulphurous acid has been used. It is well to reserve a few drops of the chromic-acid solution, to be added after the blue colour has just appeared and restore it to green. Then enough distilled water is added to bring the green liquid up to 480 grains. Then add the sublimate liquid.'

The catgut is kept twenty-four hours in the preparing liquid, and is then dried on the stretch.

N.B.—It is essential that the CrO_3 and SO_2 solutions be mixed before the $HgCl_2$ solution is added.

Catgut prepared in this way remains actively antiseptic in its substance for an indefinite period, as was shown by the following experiment:—

Some slender hanks prepared three years previously, weighing 207 grains, chopped into short segments, were placed in a small mortar and treated with enough distilled water to cover them, 2,000 grains being required for the purpose. The gut was then pressed firmly with a pestle, and the same was afterwards done three times at intervals of about three hours. The gut and water were

then transferred to a stoppered bottle for seventeen hours, when the liquid was poured off and filtered, being clear and almost colourless.

The germicidal property of the infusion was carefully tested by the late Dr. Allan Macfadyen. In spite of the large amount of water used in preparing it, he found that it destroyed the *Streptococcus pyogenes* in a quarter of an hour. When diminished to half its bulk by evaporation *in vacuo* it killed *Staphylococcus pyogenes aureus* in half an hour and deprived the resisting spores of anthrax of vitality in two hours. When further reduced by one half, although the amount of the liquid was still about twice that of the catgut to which it was applied, it killed anthrax spores in an hour.

The following is Dr. Macfadyen's account of these experiments :—

Liquid Tested.

Infusion of chromic catgut = 100 c.cm.

Organisms Used.

Bacillus anthracis, sporing potato culture.
Staphylococcus pyogenes aureus, laboratory stock culture.
Streptococcus pyogenes, virulent culture.

Methods.

Threads were soaked in emulsions of the above organisms and exposed to the action of the above liquid for varying periods of time—fifteen minutes to two hours. The threads were then washed in (1) sulphide of ammonium, (2) distilled water (sterile), and placed on sloping agar and glycerine agar at blood heat for seventy-two hours

RESULTS.

Liquid Unconcentrated.

Time	¼ Hour	½ Hour	1 Hour	2 Hours
Anthrax spores	+	+	+	+
Staphylococcus pyogenes aureus .	+	+	+ poor	+ slight
Streptococcus pyogenes . .	0	0	0	0
Controls	+	+	+	+

Liquid Reduced to Half its Bulk.

Time	¼ Hour	½ Hour	1 Hour	2 Hours
Anthrax spores	+	+	+	0
Staphylococcus pyogenes aureus .	?	0	0	0
Streptococcus pyogenes . . .	0	0	0	0
Controls	+	+	+	+

Liquid Reduced to Quarter Bulk.

Time	¼ Hour	½ Hour	1 Hour	2 Hours
Anthrax spores	+	+	0	0
Staphylococcus pyogenes aureus .	0	0	0	0
Streptococcus pyogenes . . .	0	0	0	0

But while the substance of the catgut is thus not only aseptic but powerfully antiseptic, its dry surface is liable to contamination by contact with septic material, and it is essential that, before being used, it be washed with some trustworthy germicidal liquid.

My practice has been to put the catgut, like the instruments, in 1 to 20 solution of carbolic acid about a quarter of an hour before the operation is begun. Any of the catgut that remains unused upon the reel may be afterwards kept in a similar solution for any length of time without disadvantage.

The essential precaution of purifying the surface of the catgut is, I fear, sometimes overlooked, the result being occasional suppuration attributed to defect in the ligature, while it is really the fault of the surgeon.

ON THE EFFECTS OF THE ANTISEPTIC SYSTEM OF TREATMENT UPON THE SALUBRITY OF A SURGICAL HOSPITAL

[*Lancet*, 1870, vol. i, pp. 4, 40.]

THE antiseptic system of treatment has now been in operation sufficiently long to enable us to form a fair estimate of its influence upon the salubrity of a hospital.

Its effects upon the wards lately under my care in the Glasgow Royal Infirmary were in the highest degree beneficial, converting them from some of the most unhealthy in the kingdom into models of healthiness. The interests of the public demand that this striking change should be made generally known; and in order to do justice to the subject, it is necessary, in the first place, to allude shortly to the position and circumstances of the wards.

Each of the four surgeons of the infirmary had charge of three large wards, two male and one female, besides several small ones for special cases. Of these, the most important were the male accident ward and that for female patients, the former containing the chief operation cases as well as those of injury. The third main ward of each surgeon was devoted to chronic male cases, and was in the old infirmary building; but the other two were in the 'New Surgical Hospital', erected nine years ago. This consists of four stories above a basement, each floor containing two large wards communicating with a central staircase, besides several smaller apartments. The wards are spacious and lofty, and in the centre of each are two open fireplaces, in a column which runs straight up to the roof, conveying the chimneys of all the floors, and also collateral ventilating shafts, which are warmed by the chimneys that accompany them, and, communicating with various apertures in the ceilings, form excellent means of carrying off the vitiated atmosphere, while fresh air is amply supplied by numerous windows at both sides, the beds being placed in the intervals between them, at a considerable distance from each other. Except the serious defect that the water-closets in many cases open directly into the wards, the system of construction seemed all that could be desired.

But, to the great disappointment of all concerned, this noble structure proved extremely unhealthy. Pyaemia, erysipelas, and hospital gangrene soon showed themselves, affecting, on the average, most severely those parts of the

building nearest to the ground,[1] including my male accident ward, which was one of those on the ground-floor ; while my female ward was on the floor immediately above. For several years I had the opportunity of making an observation of considerable, though melancholy, interest—viz. that in my accident ward, when all or nearly all the beds contained patients with open sores, the diseases which result from hospital atmosphere were sure to be present in an aggravated form ; whereas, when a large proportion of the cases had no external wound, the evils in question were greatly mitigated or entirely absent. This appeared striking evidence that the emanations from foul discharges, as distinguished from the mere congregation of several human beings in the same apartment, constitute the great source of mischief in a surgical hospital. Hence I came to regard simple fractures, though almost destitute of professional interest to myself and of little value for clinical instruction, as the greatest blessings ; because, having no external wound, they diminished the proportion of contaminating cases. At this period I was engaged in a perpetual contest with the managing body, who, anxious to provide hospital accommodation for the increasing population of Glasgow, for which the infirmary was by no means adequate, were disposed to introduce additional beds beyond those contemplated in the original construction. It is, I believe, fairly attributable to the firmness of my resistance in this matter that, though my patients suffered from the evils alluded to in a way that was sickening and often heartrending, so as to make me sometimes feel it a questionable privilege to be connected with the institution, yet none of my wards ever assumed the frightful condition which sometimes showed itself in other parts of the building, making it necessary to shut them up entirely for a time. A crisis of this kind occurred rather more than two years ago in the other male accident ward on the ground-floor, separated from mine merely by a passage twelve feet broad ; where the mortality became so excessive as to lead, not only to closing the ward, but to an investigation into the cause of the evil, which was presumed to be some foul drain. An excavation made with this view disclosed a state of things which seemed to explain sufficiently the unhealthiness that had so long remained a mystery. A few inches below the surface of the ground, on a level with the floors of the two lowest male accident wards, with only the basement area, four feet wide, intervening, was found the uppermost tier of a multitude of coffins, which had been placed there at the time of the cholera epidemic of 1849, the corpses having undergone so little change in the interval that the clothes they had on at the time of their hurried burial were plainly distinguishable. The wonder now was, not that

[1] Statistics collected by desire of the managers established the fact that the ground-floor wards were, on the average, most liable to pyaemia, whoever might be the surgeon in charge ; and that those on the floor immediately above came next in this respect.

these wards upon the ground-floor had been unhealthy, but that they had not been absolutely pestilential. Yet at the very time when this shocking disclosure was being made, I was able to state, in an address which I delivered to the meeting of the British Medical Association in Dublin,[1] that during the previous nine months, in which the antiseptic system had been fairly in operation in my wards, not a single case of pyaemia, erysipelas, or hospital gangrene had occurred in them ; and this, be it remembered, not only in the presence of conditions likely to be pernicious, but at a time when the unhealthiness of other parts of the same building was attracting the serious and anxious attention of the managers. Supposing it justifiable to institute an experiment on such a subject, it would be hardly possible to devise one more conclusive.

Having discovered this monstrous evil, the managers at once did all in their power to correct it. The extent of the corrupting mass was so great that it seemed out of the question to attempt its removal ; but it was freely treated with carbolic acid and with quicklime, and an additional thickness of earth was laid over it ; and, further, a high wall at right angles with the end of the building, and reaching up to the level of the first floor, so as necessarily to confine the bad air most prejudicially, was pulled down, and an open iron railing was substituted for it.

There can be no doubt that these measures must have proved salutary. But even if it were admitted that they cured completely the particular evil against which they were directed, it would still have to be confessed that the situation of the surgical hospital has been far from satisfactory Besides having along one of its sides the place of sepulture above alluded to, one end of the building is conterminous with the old Cathedral churchyard, which is of large size and much used, and in which the system of ‘ pit burial ’ of paupers has hitherto prevailed. I saw one of the pits some time since, having been requested to report upon it by one of the civic authorities, who is also a manager of the infirmary, and who, having accidentally discovered what was going on, at once took steps to prevent for the future the occurrence of anything so disgraceful. The pit, which was standing open for the reception of the next corpse, emitted a horrid stench on the removal of some loose boards from its mouth. Its walls were formed, on three sides, of coffins piled one upon another in four tiers, with the lateral interstices between them filled with human bones, the coffins reaching up to within a few inches of the surface of the ground. This was in a place immediately adjoining the patients’ airing ground, and a few yards only from the windows of the surgical wards. And the pit which I inspected seems to have been only one of many similar receptacles, for the *Lancet*

[1] See p. 45 of this volume.

of September 25th contains a statement, copied from one of the Glasgow newspapers, that 'the Dean of Guild is said to have computed that five thousand bodies were lying in pits, holding eighty each, in a state of decomposition, around the infirmary'.[1] Just beyond the churchyard rises an eminence covered by an extensive necropolis, which, however, from its greater distance, must have comparatively little deleterious influence. When I add that what is called the fever hospital,[2] also a long four-storied building, extends at right angles to the new surgical hospital, separated from it by only eight feet, and that the entire infirmary, containing 584 beds, stands upon an area of two acres, and that the institution is almost always full to overflowing,[3] I have said enough to show that the wards at my disposal have been sufficiently trying for any system of surgical treatment. Yet, during the two years and a quarter that elapsed between the Dublin meeting and the time of my leaving Glasgow for Edinburgh, those wards continued in the main as healthy as they had been during the previous nine months. Adding these two periods together, we have three years of immunity from the ordinary evils of surgical hospitals, under circumstances which, but for the antiseptic system, were especially calculated to produce them.[4]

It may be well to mention in detail some facts regarding the comparative frequency, before and after the period referred to, of the three diseases to which surgical wards have hitherto been peculiarly liable—namely, pyaemia, erysipelas, and hospital gangrene.

And first of pyaemia. This fearful disease used to occur principally in two classes of cases—namely, compound fractures and the major amputations. In compound fracture, it was so rife just before the introduction of the antiseptic system that I had one of the sulphites administered internally as a prophylactic, in accordance with Polli's views, to every patient admitted with this kind of injury, though I cannot say that we observed any distinct evidence of advantage from the practice. But since I began to treat compound fractures

[1] I doubt if even my sense of the importance of the subject I am dealing with would have induced me to enter into these disagreeable details, were I not able at the same time to bear my testimony to the zealous manner in which the managers of the infirmary and the Town Council are exerting themselves to correct the evils referred to. I understand that it is in contemplation to abolish entirely intramural interment in Glasgow.

[2] About half the wards of the fever hospital are used for surgical cases.

[3] The rapid increase of Glasgow has rendered the infirmary, in spite of considerable additions of late years, quite inadequate to the wants of the population; but this evil will shortly be remedied by the construction of a general hospital in connexion with the new College.

[4] The antiseptic system was commenced nearly five years ago, but was for the first two years employed almost exclusively in compound fractures and abscesses, which form but a small proportion of surgical cases, so that the system cannot be said to have been in operation for more than three years with reference to the subject of the present paper.

on the antiseptic system, while no internal treatment has been used, I have not had pyaemia in a single instance, although I have had in all thirty-two cases—six in the forearm, five in the arm, eighteen in the leg, and three in the thigh. These cases do not include those in which the injury was so great as to demand immediate amputation. But it must be remarked that many of the limbs saved were so severely injured that I should formerly have removed them without hesitation. I almost forget the kind of considerations which used to determine me to amputate under the old treatment; though I know that experience taught us that it was only in comparatively mild cases that it was justifiable to attempt to save the limb. Now, however, there is scarcely any amount or kind of injury of bones, joints, or soft parts which I regard as inconsistent with conservative treatment, except such destruction of tissue as makes gangrene of the limb inevitable as an immediate consequence.

But I may take this opportunity of observing that the attempt to save a limb which, under ordinary treatment, would be subjected to immediate amputation, ought not to be made lightly, or without a thorough acquaintance with some trustworthy method of carrying out the antiseptic system; by which I mean, not the mere use of an antiseptic, however potent, *but such management of the case as shall effectually prevent the occurrence of putrefaction in the part concerned.* Without this such endeavours are far worse than useless; for by the time that local disturbance and constitutional disorder have made it apparent that the antiseptic means have failed, the patient is so much prostrated by irritation and blood-poisoning, that the operation, if performed, is probably too late; and thus a loose and trifling style of 'giving the treatment a trial' swells the death-rate at once of compound fracture and of amputation.

On the other hand, the surgeon will not on this account be justified in contentedly pursuing the old practice of primary amputation; for the antiseptic means which it has been the main labour of the last five years of my life to improve are now so satisfactory that any one duly impressed with the importance of the subject, and devoting to it the study and practical attention which it demands, will, with little trouble to himself, securely attain the results which he desires.

I lately visited my wards in Glasgow after an absence of some weeks, and saw, amongst other cases, a compound dislocation of the ankle in a man who had fallen about four feet from the platform at a railway station, and lighted on the outer side of the right foot, which had been forced violently inwards, producing a contused and lacerated wound, about four inches long, crossing the external malleolus, and communicating with the articulation. When I saw the patient the wound had been converted into a superficial sore, cicatrizing rapidly; and

there had been from first to last no deep-seated suppuration, nor any local or constitutional disturbance. I asked my then house surgeon, Mr. James Coats, with whom the most critical part of the treatment had rested, whether he could reckon pretty securely upon such results. He replied, 'With certainty.' I asked the question for the sake of others who were standing by, having little doubt what the answer would be, for when I left him in charge I felt sure that the antiseptic management of the cases would be as satisfactorily conducted as if I were present.

At the same time, it is only right to add, that when he entered upon his office, though convinced of the truth of the theory of the antiseptic treatment, he by no means felt the confidence in carrying it out which he has since acquired; and if an able man like Mr. Coats, imbued with the principles which I have striven to establish, required some practical initiation into the subject before he could be regarded as trustworthy, still more must such be the case with those who, educated in the old system, and long habituated to its practice, have to unlearn cherished ideas and instinctive habits.

But, returning from this digression, I must now speak of pyaemia after the major amputations, before and after the introduction of the antiseptic system.

The hospital records are unfortunately imperfect for one of the three years immediately preceding the antiseptic period. In the other two years, the mortality after amputations in my wards may be gathered from the following tables:—

Before the Antiseptic Period.

1864

Seat of Amputation.	No. of Amputations.	Recoveries.	Deaths.
Shoulder	1	0	1
Arm	3	1	2
Forearm	3	2	1
Thigh	1	1	0
Leg	4	3	1
Knee	2	1	1
Ankle	3	2	1
Totals	17	10	7

1866

Seat of Amputation.	No. of Amputations.	Recoveries.	Deaths.
Arm	2	1	1
Elbow	1	0	1
Forearm	2	2	0
Thigh	4	0	4
Knee	6	4	2
Leg	1	1	0
Ankle	2	1	1
Totals	18	9	9

On the other hand, we have—

During the Antiseptic Period.

1867

Seat of Amputation.	No. of Amputations.	Recoveries.	Deaths.
Arm	1	1	0
Forearm	2	2	0
Knee	2	2	0
Leg	1	1	0
Ankle	1	1	0
Totals	7	7	0

1868

Seat of Amputation.	No. of Amputations.	Recoveries.	Deaths.
Shoulder	1	1	0
Forearm	2	2	0
Thigh	1	1	0
Knee	8	5	3
Ankle	5	5	0
Totals	17	14	3

1869

Seat of Amputation.	No. of Amputations.	Recoveries.	Deaths.
Shoulder	2	2	0
Arm	2	2	0
Forearm	2	1	1
Thigh	1	0	1
Knee	3	2	1
Leg	3	3	0
Ankle	3	3	0
Totals	16	13	3

Comparing the aggregate results, we have—

Before the antiseptic period, 16 deaths in 35 cases ; or 1 death in every $2\frac{1}{5}$ cases.

During the antiseptic period, 6 deaths in 40 cases ; or 1 death in every $6\frac{2}{3}$ cases.

These numbers are, no doubt, too small for a satisfactory statistical comparison ; but, when the details are considered, they are highly valuable with reference to the question we are considering. This is especially the case with amputation in the upper limb, where neither injuries requiring primary amputation nor the operations involve, as a general rule, much loss of blood or shock to the system ; so that, if death does occur, it is commonly the result of the wound assuming unhealthy characters. It happens that there were twelve amputations altogether in the upper limb in each of the two periods referred to. Of the twelve cases before the antiseptic period, no fewer than six died—a frightful mortality certainly. And it is recorded that, of those six, four died of pyaemia and one of hospital gangrene. Also that one of those which recovered had pyaemia ; but, though the symptoms were well marked and severe, presented an example, unhappily too rare, of recovery from the disease.

Very different was the result of the corresponding amputations during the antiseptic period. Eleven of the twelve cases recovered; and the one death which did occur was not the result of the operation, but took place in spite of it, from pyaemia, which had resulted from fetid suppuration in a metacarpal bone, and continued after I had removed the hand, in the faint hope that the constitutional mischief might be thrown off when its original source had been taken away. Some of the successful cases, I may add, were by no means favourable subjects for operation: as, for instance, a completely shattered hand in a very aged person; the avulsion by machinery of nearly the entire arm, one of the flaps of the amputation at the shoulder-joint being left contused and lacerated as it had been formed by the injury;[1] and, again, an enormous osteoid cancer of the upper end of the humerus, involving the deltoid muscle, and permitting only the formation of skin flaps, attended with profuse haemorrhage, in a patient already anaemic from the disease.

In the lower limb, twenty-eight amputations in all were performed during the antiseptic period. Out of these, death took place in five; but was generally sufficiently accounted for by the severity of the case, as when the thigh was amputated immediately below the hip-joint in a patient greatly exhausted by haemorrhage from malignant disease; or, to take another example, when primary amputation was performed at the knee on one side, and immediately below it on the other, in a man who had sustained very severe injuries to both legs, and had been transported a considerable distance by railway to Glasgow.

In one case only did pyaemia result from the operation—viz. after amputation at the knee in a young man of weakly constitution, where putrefaction occurred in the stump through mismanagement. Here the symptoms of pyaemia presented themselves during life, and the femoral vein was found loaded with pus on dissection. When putrefaction occurs after such an operation, there is no security against pyaemia, even in private practice; and a single instance of the kind in three years, and that in a feeble subject, is certainly no evidence of any peculiarity in the hospital atmosphere.

In mentioning the fact that putrefaction occurred from mismanagement, I do not wish to be understood as implying that it can always be avoided in stumps. In the present state of surgical practice, this is far from being the case. When sinuses exist in connexion with a diseased joint, putrefaction is present in them at the outset; and even if they are injected with an antiseptic solution before the operation, it can never be certain that the liquid penetrates to every recess of these often complicated passages, or destroys the vitality of the putrefactive organisms, lurking, perhaps, in portions of lymph or slough.

[1] This case was treated by my colleague, Dr. Dunlop, during my temporary absence.

And if a single such organism remain alive, it will propagate and spread in the wound as soon as the antiseptic applied at the time of the operation has been absorbed into the circulation; and any external antiseptic dressing will, under such circumstances, be of course entirely nugatory. It is, I suspect, for want of bearing this point in mind that disappointment has often been experienced in applying antiseptic treatment to amputations and excisions. The full possible benefits of the system can never be obtained in such cases till it shall be deeply impressed upon the profession and the public that abscesses, more especially those in connexion with diseased joints, must never either be allowed to break of themselves, or be opened without antiseptic precautions.[1]

I am bound to add that there is another respect in which the antiseptic principle has not yet had justice done to it in the larger amputations in the lower limb. Of all incised wounds, these have proved the most difficult to manage; and putrefaction has repeatedly occurred in my practice, even where no sinuses were present. It was so in the two cases above referred to, of amputation just below the hip-joint for malignant disease, and double primary amputation for injury. Considering the condition of those patients on the day after the operation, I believe both would have recovered had we succeeded in avoiding putrefaction, which, apart altogether from the risk of pyaemia, terribly aggravates formidable cases, like those, by the irritation and prostration which it occasions. Hence we may fairly look for better results in the future from amputation in the lower limb. For I am satisfied that the difficulties of the antiseptic management are not insuperable. I have devoted much attention to this branch of the subject during the last twelve months, and steady progress has been made in it; so that the proportion of stumps in which healing has taken place without any deep-seated suppuration has been markedly increasing, and I anticipate that before long we shall be able to reckon with certainty on the absence of putrefaction in all cases where sinuses are not present.

But to return to the subject of pyaemia. The two cases above alluded to were the only instances of its occurrence in my department during the antiseptic period. One of them requires further notice here. It belonged to a class of injuries in which the benefits of the antiseptic system have been conspicuously apparent—namely, severe contused wounds of the hand or foot, such as are

[1] The practice which I have found to answer best in amputations and excisions in parts affected with sinuses is, after injecting the sinuses with a powerful antiseptic, to apply to the cut surface a pretty strong solution of chloride of zinc (say forty grains to an ounce of water), such as was recommended by Mr. Campbell De Morgan, and then employ an external antiseptic dressing, in the hope, though never in the certainty, that putrefaction will be avoided. Chloride of zinc, having the peculiarity of producing a remarkably persistent antiseptic effect upon the cut surface, protects it during the dangerous period preceding granulation, when the recently divided tissues are both sensitive and prone to absorption; so that even if putrefaction does occur, the risk of inflammation and pyaemia is greatly diminished.

very frequent in a great centre of manufacture like Glasgow. Formerly there were no injuries more unsatisfactory to deal with. The uncertainty of the extent of the damage inflicted by the contusion made it a most perplexing question where amputation should be performed. On the one hand, if too little was removed, sloughing of the flaps ensued, or diffuse suppurative inflammation of the weakened tissues infiltrated with extravasated blood ; and, on the other hand, if it was determined to avoid that error and to amputate through perfectly sound tissues, an extravagantly large portion of the limb was often sacrificed. It is therefore an unspeakable satisfaction to be able to avoid amputation altogether in such cases, merely taking away such portions as may be actually destroyed, and leaving the weakened tissues in the vicinity to recover themselves quietly, instead of perishing under the irritating and poisoning influence of putrefaction ; while any dead portions that may remain are absorbed more or less completely, like the extravasated blood, and replaced by tissue of new formation. If the history of all the contused wounds of the hands and feet that have been treated in my wards during the last three years were recorded, including many compound fractures not reckoned as such in our classification and several compound dislocations, it would be enough to convince the most sceptical of the advantages of the antiseptic system.

But the case to which I am now alluding was an exception to the general rule of satisfactory progress. It was a severe injury to the hand from machinery. My then house surgeon, who had only just entered upon his office, and had not as yet the confidence in the antiseptic system which he soon afterwards acquired, took it for granted that I should amputate the hand, and committed the error of leaving it till my visit on the following day, without adopting efficient antiseptic measures. When I saw the case I decided to try to save the greater part of the hand, and endeavoured to correct the mistake which had been made. Putrefaction, however, ensued, and after some days pyaemia occurred, and continued, as before stated, in spite of amputation of the hand. On dissecting the parts, one of the metacarpal bones was found split up, with putrefactive suppuration developed in its interior. Under such circumstances pyaemia might occur in a perfectly sound constitution and in the most healthy atmosphere, just as, in Cruveilhier's highly instructive experiment, suppurative phlebitis of the femoral vein and its branches, exactly corresponding to that which is seen in traumatic pyaemia, was induced in a healthy dog by introducing into the vessel a bit of wood which, from its porous nature, could not but originate putrefaction.[1]

[1] See Cruveilhier's *Anatomie Pathologique*, livraison xi, where will also be found the records of important experiments, proving how readily liquids introduced into the interior of bones pass into the general circulation.

Considering, then, the circumstances of the only two cases of pyaemia which have occurred in my department during the three years of the antiseptic period, I am justified in saying that the wards have been completely freed from their former liability to this frightful scourge.

Next of erysipelas, a disease which, though not so fatal as pyaemia, used not infrequently to occasion death amongst my patients. During the antiseptic period several cases have been admitted into my wards from without, but one only has originated in them. This occurred in a young man with disease of the foot, accompanied by sinuses extending into the leg. I performed amputation at the ankle, but putrefaction continued in the sinuses ; and after the lapse of a considerable period erysipelas occurred in connexion with them. He recovered from the complaint, and after a while went to his lodgings for change of air, with the sinuses still unhealed, and subsequently had another attack of erysipelas there, implying that the tendency to it was in his own system rather than in the locality. That such was really the case was afterwards fully demonstrated. The sinuses refusing to heal, and disease recurring in the bone, he was readmitted under my care, and I performed amputation in the leg above the sinuses. The stump healed without any deep-seated suppuration, presenting a very good example of the result of a modification of Mr. Teale's method of amputation ; and I requested him to ascertain, by Mr. Teale's plan of introducing circular pieces of flannel into the socket of the artificial limb, how much of his weight he could conveniently rest upon the end of the stump. As he did not call to report the result on the day arranged, I inquired into the cause, and learned that the stump had been seized with a third attack of erysipelas, although perfectly cicatrized without sinus or sore of any kind.[1] Thus, as regards erysipelas, our only exception to perfect immunity from the disease during the three years was one that strikingly proves the rule.

It remains to speak of hospital gangrene. This was formerly both frequent and severe amongst my patients. It often grievously marred the most promising results of surgery, and sometimes committed fearful ravages. Thus, I have known a boy admitted with a small superficial wound near the elbow, in which hospital gangrene occurring caused such destruction of tissue, deeply as well as superficially, in spite of the most energetic treatment, that it became necessary to amputate the limb. Now and then it led to a fatal result, as in one of the amputations before referred to. In that case I removed the arm at the shoulder-joint for injury in a boy, and for some time all went on well, till I regarded him as perfectly safe ; but hospital gangrene came on in the

[1] This case seems to me to possess considerable interest, as something intermediate—as it were a connecting link—between traumatic and idiopathic erysipelas.

stump, and, advancing insidiously in all directions, defied my best attempts to check it, and had reached beyond the sternum before the poor fellow sank exhausted from its effects.

The contrast under the antiseptic system has been most striking. For the first nine months, as before mentioned, we had not a single case of the disease. Since that time it has shown itself now and then, but in a mild form, invariably yielding to treatment, never occurring in recent cases, but only in old sores weakened by the influence of surrounding cicatrix. But even this has been very rare, and I do not recollect more than one example of it during the last year. In short, hospital gangrene, like pyaemia and erysipelas, may be said to have been banished by the antiseptic system.

Such being the case, I have insensibly relaxed in different ways my former vigilance regarding the wards. I have allowed cribs for children to be introduced without remonstrance, having practically the effect of increasing the number of beds for adults ; and I have, in the pressure of deficient accommodation, often permitted two children to be put in one bed—a thing which I should formerly not have thought of. I used to make a point of having both the large fires in each ward kept alight night and day during the heat of summer, for the sake of making the ventilation as perfect as possible. But during the last season the nurses were left to follow their inclination, and keep only one of the fires lighted. I may add that my wards have remained during the three years without the annual cleaning, which used to be thought essential. On my asking the superintendent the reason for the omission, he replied that, as those wards had continued healthy, and there was nothing dirty in their appearance, it had seemed unnecessary to disturb them. Thus the wards have been in various respects subjected to greater trial than usual, and yet have remained, as I may repeat without any exaggeration, models of healthiness.

That such should have been the case under the unfavourable hygienic conditions above referred to seems at first sight very surprising. The immediate vicinity of a burying-ground such as has been described, together with the position of the wards at the base of a hospital of four stories, with the air confined by neighbouring buildings, may seem conditions utterly inconsistent with health in the patients. That these circumstances were very unfavourable is undoubtedly true ; and that they were highly injurious before the antiseptic period seems clearly indicated by our experience. But a little consideration will show that it is not unreasonable to suppose them of secondary importance—as aggravators of the evil, rather than the essential causes of it. The corpses in the places of sepulture beside the infirmary were for the most part covered by at least some inches of earth, which has a most powerful effect in checking the

evolution of noxious effluvia ; and even the foul gases from the open pits were perpetually diluted by the air with which they mingled, so that but a small proportion of them would enter the wards ; and accordingly, when the patients were cleared out for the purpose of the annual cleaning, there was nothing in the wards to offend the nose. But the emanations from sores are poured directly into the confined atmosphere in which the patients are ; and any one familiar with the faint sickly smell commonly perceptible in surgical wards under ordinary treatment, and still more with the stench which prevails at the time of the daily dressing, will readily understand that putrid exhalations from the patients may be a source of mischief, compared with which the other circumstances alluded to may be of comparatively trifling consequence.

With the object of getting rid of this great evil as much as possible, I have used antiseptic means, not only where they are of essential importance for the treatment of the individual case concerned, as in recent wounds and abscesses, but also in superficial sores. For though granulating surfaces will commonly heal well enough under a putrid dressing (for such the cleanly water dressing becomes within a few hours of its application), every case so treated furnishes its quota to the vitiation of the general atmosphere of the ward. Hence, for the sake of the inmates generally, it is obviously desirable that healing sores should be dressed with some application which, while permitting, or, if possible, favouring cicatrization, should prevent odour. For this purpose some dressing unstimulating, but at the same time persistent in antiseptic action, is requisite, —a combination which I have sought in various different forms to obtain, and, of late more especially, with very satisfactory results, so that while the healing of superficial sores proceeded with greater rapidity than under water dressing, all my sixty patients might sometimes be dressed without the odour of putrefaction being perceptible in one of them.

The result of this great change has been such as to demonstrate conclusively that the exhalations from foul discharges are the essential source of the insalubrity of surgical wards ; and that when this is effectually suppressed, other conditions, which we are accustomed to regard as most pernicious, become powerless to produce serious evil.

It is obvious that the facts recorded in this paper are of extreme importance with reference to the vexed question of hospital construction. With the view of assimilating the atmospheric condition of our large hospitals to that of a private dwelling, it has been lately proposed to do away with them altogether in their present form, and to substitute for them congeries of cast-iron cottages, capable of being occasionally taken down, cleansed, and reconstructed—a plan which, besides involving enormous expense, would interfere most seriously

with efficient supervision of the patients, and with the teaching of students at the bedside. But from what has been related above, it is plain that no material alteration of the existing system will be required. We have seen that a degree of salubrity equal to that of the best private houses has been attained in peculiarly unhealthy wards of a very large hospital, by simply enforcing strict attention to the antiseptic principle. And, considering the circumstances of those wards, it seems hardly too much to expect that the same beneficent change which has passed over them will take place in all surgical hospitals, when the principle shall be similarly recognised and acted on by the profession generally. The antiseptic system is continually attracting more and more attention in various parts of the world; and, whether in the form which it has now reached, or in some other and more perfect shape, its universal adoption can be only a question of time. The noble institutions of which our country is justly proud, admirably adapted alike for the treatment of the sick and the instruction of the student, will then be cleared of the only blot that now attaches to them—the malignant influence of impure atmosphere.

Edinburgh, December 1869.

REMARKS ON A CASE OF COMPOUND DISLOCATION OF THE ANKLE WITH OTHER INJURIES; ILLUSTRATING THE ANTISEPTIC SYSTEM OF TREATMENT

[*Edinburgh*, March 26, 1870 (Pamphlet).]

This case was first alluded to as follows in a Lecture delivered on the 14*th of February* 1870 :—

The next case, Gentlemen, which I wish to bring under your notice, is that of a labourer thirty years of age, who was seriously injured on a railway three days ago. He was standing on the line, about a mile out of Edinburgh, at 6 a.m., when he suddenly saw an engine close upon him coming at considerable speed, and he had only just time to turn half round before it struck him on the left shoulder and hurled him to the ground between the rails. On recovering consciousness, he found himself unable to walk ; but about half an hour later, his cap having been discovered above the buffers of the locomotive, the men in charge of the engine went in search of the owner, and, finding him lying helpless, conveyed him to the infirmary. When I saw him about 8.30 a.m., he was suffering considerably from shock ; and he feared, from severe pain which he felt in his chest, that he had received some serious internal injury—an apprehension which has happily proved groundless. I found the left foot much displaced inwards, and the external malleolus protruding through a vertical wound in the integument two or three inches in length. The tip of the malleolus had been broken off, and remained attached to the external lateral ligament ; while the extremity of the protruding part was comminuted. The internal malleolus was of course fractured, as a necessary condition of such a displacement of the foot. Now, Gentlemen, if you were experienced surgeons, you would know that this was a most formidable injury. Recoveries from it were formerly exceptional. Mr. Syme informs me that at one time, on looking into the hospital records, he found that the last fourteen cases of compound dislocation of the ankle admitted into the infirmary had all ended fatally. He therefore came to regard amputation at the ankle as the best treatment in most cases ; though he sometimes modified his practice so far as to content himself with removing the end of the tibia, so converting the case into one of excision of the ankle.

In our patient, however, neither of these procedures has been adopted. For the purpose merely of facilitating the return of the protruding malleolus,

I nipped off a portion of it with cutting-pliers,[1] and, with the same object, enlarged slightly with scissors the lower end of the rent in the skin, which opposed a barrier to its passage. But to all intents and purposes the dislocation was simply reduced. The case, however, was treated antiseptically. Watery solution of carbolic acid, as strong as it can be made (one part of the crystals to twenty of water), was thrown into the joint with a syringe, the edges of the skin being held together to prevent its escape and cause its penetration to all the internal recesses of the wound; and this was further promoted by free manipulation of the injured part while the fluid was still in the interior. There was a time when we should have thought that to introduce an irritating liquid like this into the ankle-joint would be to take an unwarrantable liberty with the articulation. But we now understand that the transient irritation caused by the antiseptic lotion is nothing compared with the abiding influence of the far more acrid products of putrefaction. In the operation which you saw me perform just now [the removal of a fatty tumour], a lotion of half the strength (1 to 40) was employed; experience having proved that this is sufficient to ensure destruction of the putrefactive organisms in a wound just made, and made by the surgeon himself. But when the injury has been received some time before you see the patient, and inflicted, as in the present instance, in a rude way, involving the chance of foreign material having been introduced and mixed, perhaps, with clots of blood lying in inaccessible recesses of the wound, it seems wise to employ as strong a solution as water will produce. And as this will be your only chance of acting upon putrefactive particles lodged in the interior—as the work of their destruction must be done once for all at the outset—do not be afraid of dealing very freely with the injured part in introducing the germ poison. [It is a mistake to mingle spirit of wine or glycerine with the watery solution used for injecting the wound. The admixture of either of these materials with water containing a given amount of the acid in solution, gives it a greater hold upon the acid, and renders the lotion more bland, and at the same time more persistent in its action; and this may, under certain circumstances, be very useful for the purpose of an external dressing. But for the preliminary treatment of the interior of the wound an agent potent for the moment, but transient, is called for, to kill the putrefactive organisms, and, as soon as this is done, to leave the wound as speedily as possible to recover from the inevitable irritation of the antiseptic; and for this purpose no vehicle seems better for the acid than simple water.[2]] The liquid introduced having been squeezed out, the process of injection and manipulation was performed

[1] The portion removed was covered at its deeper surface with articular cartilage.
[2] The remarks included within brackets were made on another occasion.

a second time for greater security, and the skin in the vicinity having been previously well washed with the lotion, to destroy organisms adhering to it or to the hairs, an external dressing was applied, similar to that which you have seen used after removal of the fatty tumour. Lac-plaster was wrapped in two layers round the limb, from three or four inches above the upper extremity of the wound to as far below its lower end—that is to say, extending well up the leg and embracing the heel and instep ; the foot meanwhile being held in good position. A cloth, to absorb the blood and serum which would be discharged from beneath the margins of the plaster, was then bandaged on, and a splint applied to the inner aspect of the leg and foot. [The lac-plaster has been very much improved of late, by being incorporated with a soft cloth, instead of being spread upon starched calico. It is thus rendered beautifully flexible, and at the same time much more durable, the cloth incorporated with it enabling it to withstand any amount of wear and tear. But as in this form it is very thin, it is well, where much discharge is anticipated, or when a long time is intended to elapse between the dressings, to use it in two layers, so as to double the store of the acid in the application.]

But, Gentlemen, the compound dislocation of the ankle was not the only injury which this poor man received. Observing some blood about his hair, I examined the head, and found four scalp-wounds, varying in length from two to five inches, three of them exposing the bone, into which black dirt had been ground—probably, as he suggests, by the fire-pan of the engine. We used to reckon that when the bone was thus extensively exposed in a scalp-wound, and subjected at the same time to such violence, the cure was pretty sure to prove tedious, protracted by the exfoliation of osseous scales of greater or less thickness. There was at the same time more or less risk of head symptoms or of erysipelas. It is, therefore, very satisfactory in such cases to be able to reckon on primary union under antiseptic management. The region occupied by the wounds being extensive, the greater part of the scalp was shaved, and thoroughly washed with the strong antiseptic lotion ; and the wounds were treated just like that at the ankle, except that their edges were approximated by antiseptic sutures. [The material which I have used of late for this purpose is silk steeped for a while in a mixture of melted bees-wax with a certain proportion of carbolic acid—say a tenth part. As the silk is taken out of the hot liquid, it is drawn through a dry cloth to remove the superfluous wax ; after which it may be wound on a reel, and kept in any close vessel. The wax, besides giving the knot a better hold, prevents the antiseptic from being washed out of the thread, and also, filling up the interstices of the fibres, renders the silk incapable of imbibing stimulating liquids ; and so confers an unirritating quality corre-

sponding to that of the metallic suture, over which the suppleness of the thread gives it a great superiority.] When all had been stitched up, each wound was once more injected with the strong watery solution, to correct any mischief that might possibly have been introduced by regurgitation of blood that had oozed into the cavity during the insertion of the stitches. A well-overlapping cap of lac-plaster, in double layer, was then applied, surrounded by a cloth to absorb discharge, secured by bandage and pins.

I cannot too strongly impress upon you the importance of having the plaster extend freely beyond the wound at every part, so that the discharge may have to travel a considerable distance beneath the impermeable antiseptic layer before reaching the sources of mischief externally. It is only in this way that you can guard securely against the spread of the putrefactive fermentation into the wound. Yet there is nothing in the antiseptic treatment that I find more apt to be neglected.

After I had left the patient, Dr. Cleaver [the house surgeon] discovered a compound fracture of the right olecranon. The patient thinks he must have fallen upon his elbow ; and in this he is no doubt correct, the fracture having been thus caused by direct violence. The wound was not large (about an inch in length), but, from the relations of the bone, it necessarily communicated with the articulation. Here, then, was another injury, in itself sufficiently serious—a compound fracture into the elbow-joint. This Dr. Cleaver treated in a manner similar to that in which I had dressed the ankle, and applied an anterior splint to maintain extension of the elbow.

Now, Gentlemen, I do not hesitate to say that if our antiseptic means succeed as such—that is to say, if putrefaction is prevented from occurring in the wounds—neither of these severe injuries, the compound dislocation of the ankle, the compound fracture into the elbow-joint, nor the scalp wounds exposing and injuring the bone, will occasion either local or constitutional disturbance. You may perhaps think me bold to speak in this confident way at so early a period of the case, at the beginning of the fourth day, the very time when, under ordinary treatment, the region of the ankle would be red, swollen, and painful, preliminary to suppuration, and the pulse rising, with other indications of increasing fever. But the progress of the patient already goes far to justify me. All the injured parts are as yet in a perfectly quiet state, his pulse is daily descending, his tongue is clean and moist, and he relishes his food, and complains of no pain whatever, except that of the contusions of his chest and shoulder. *You* cannot suspect me of exaggeration, for you have only to go to the patient's bed and inquire for yourselves ; and any of you who are disposed to witness the dressing will see it done to-morrow at the visit hour.

But besides the favourable condition of this patient hitherto, I have ample experience to found upon. Since my attention was first drawn to antiseptic surgery I have been concerned in four other cases of compound dislocation of the ankle. One of them was treated in the Glasgow Infirmary just before I left it. The displacement of the foot was inwards, as in our patient, though produced in a very different way.[1] The treatment also was the same; and the wound, which was large, became a superficial sore without suppuration or any local or constitutional disturbance.

Another of the cases was also a dislocation inwards, caused by a lady being thrown out of a dog-cart. She was not under my care, but I was in so far concerned in the treatment that the son of her medical attendant (Dr. Coats, of Glasgow) being at that time one of my dressers, he was asked by his father to employ the means which he had seen me use at the hospital. In accordance with my practice at that time, an oily solution of carbolic acid was introduced into the joint and into the rest of the wound, and a layer of putty, rendered antiseptic by the admixture of a certain proportion of the acid, was used for the external dressing. The means were different, but their object was the same. The oily solution destroyed organisms existing in the wound; and the putty, like the lac-plaster, impermeable to watery fluid, communicated the volatile antiseptic stored up in its substance to the discharge that flowed out beneath it. The case was published by Dr. Coats,[2] who told how, after the first smarting caused by the acid had subsided, the patient was free from the pain previously experienced, and never after had any uneasiness in the part. Here also the wound closed without any deep-seated suppuration or any febrile disturbance.

In a third case, a gentleman about sixty years of age, of heavy frame, slipped in going downstairs, and the foot was driven forcibly outwards, the fibula being broken, while the internal malleolus was thrust through the integument. I saw the patient in conjunction with Dr. George Buchanan, of Glasgow; and Mr. Berkeley Hill, of London, happening to be on a visit to me at the time, witnessed the first dressing. The lac-plaster was used, but in a way which I have since abandoned, so that I need not trouble you with its details. [After the joint had been injected with watery solution of carbolic acid, and the dislocation reduced, a bit of thin block-tin was placed over the wound to protect it from the stimulating action of the acid in the plaster wrapped round the foot. This was surrounded with a cloth and bandage, which were afterwards daily touched with a strong solution of carbolic acid in oil, to renew a supply of the antiseptic to the lac beneath, which was permanently retained. The tin has

[1] See p. 127 of this volume.

[2] See *Lancet*, May 2, 1868.

since been superseded; and I have found it, on the whole, better to change the entire dressings occasionally, in the manner to be described in the sequel.] Though the patient was of gouty habit, and in other ways by no means a very favourable subject, his progress was all that could have been desired had the case been one of simple fracture. [Not one drop of pus appeared till, five weeks having elapsed, and a little serous discharge still continuing, the deeper dressings were removed for the first time, and disclosed a superficial sore with pouting granulations, which healed in a few days under an astringent lotion.]

The fourth case was one in which the injury was inflicted by myself, but was of the same essential nature as those caused accidentally, though its effect was to remedy, not to produce, displacement. The foot had been driven backwards and outwards by the violence which occasioned a simple fracture of the fibula and internal malleolus four months before; and the faulty position having continued during the union of the fragments, the limb was perfectly useless, and the patient, a young man of twenty-nine, had the prospect of going on crutches for the rest of his life. Relying on our antiseptic means, I did not scruple to divide with pliers the callus of both tibia and fibula, though I knew that in so doing I was opening into the ankle-joint. For the case differed in this important particular from those which result from accident, that I could guard with certainty against the introduction of putrefactive mischief while making the wounds; whereas in the accidental cases we cannot help feeling a degree of uncertainty till the first few days are over, whether the organisms introduced before we see the patient have been all destroyed, though in truth the method by injection and manipulation which I have described seems to have reduced this to something very nearly approaching certainty. The foot having been drawn forcibly into its proper position by means of pulleys, and retained by appropriate splints, while an external antiseptic dressing was employed on the same principle as the putty and lac-plaster, though of different materials, the wounds became superficial without suppuration and without the slightest inflammation or fever;[1] and I have the satisfaction of knowing that he, like the other patients, has now a sound and useful foot.

You see, then, Gentlemen, that I had reason for the confidence with which I expressed myself.

In a Lecture on the 17th of February the following remarks were made:—

The case of complicated injury which we were considering three days since goes on in accordance with our anticipations; and I wish now to say something regarding its subsequent management and progress.

[1] For further details of this case, see p. 72 of this volume.

The dressings were changed entirely on the day after the accident. [In doing this the greatest care is requisite. For the antiseptic injected into the wound on the previous day having been absorbed into the circulation, the extravasated blood, and any portions of tissue killed by the violence of the injury, are as susceptible of putrefaction as if no such treatment had been pursued; and my experience leads me to believe that if, when the dressings are removed, a single drop of serum were to be pressed out by the movements of the limb and then regurgitate into the interior, after being exposed even for a second to the influence of septic air, putrefaction would be pretty certain to occur. The skill required to guard against this risk during the first few days, before the wound has consolidated, used to be a serious drawback to the treatment. But the difficulty and uncertainty arising from this cause have been changed to facility and security by a most simple means—the employment of a syringe, the nozzle of which is inserted beneath the margin of the lac-plaster, and, as this is raised, a stream of weak watery solution of carbolic acid (1 to 40) is made to play upon the wound till a piece of calico, soaked with the same lotion, has been placed upon it by an assistant, as a temporary security until the plaster is reapplied. Any examination of the wound that may be desired is made with freedom through the transparent solution thrown over it by the syringe, the wound being never left for an instant without an antiseptic guard. The cloths outside the lac-plaster adhere to its edges through drying of the discharges which they absorb, and care must be taken in removing them to hold the plaster down over the region of the wound, so that it may not be, even for a moment, dragged up along with them. These details, while essential to success, are, happily, easy of execution.]

The dressing on the day after the accident and subsequently has differed from that used in the first instance in this respect, that, before applying the lac-plaster, the wound itself was covered with a layer of material designed to protect it from the stimulating and irritating influence of the carbolic acid in the antiseptic stratum. You have often seen this 'protective' in use in other cases, but I desire now to direct your attention to it more particularly.

Of all those who use antiseptics in surgery, I suspect that I apply them least to the surface of the wound. After the first dressing, the object which I always aim at is to have the material in contact with the exposed tissues approximate as closely as possible to the perfectly bland and neutral characters of the healthy living textures. If you consider the circumstances of a simple fracture, which you cannot too often call to mind if you wish to keep your ideas clear and right upon this subject—if you remember how the severe contused internal wound, with the interstices of the mangled tissues loaded with extra-

vasated blood, recovers quickly and surely under the protection of the unbroken integument, it is plain that all that is required in an external wound is to guard it against the disturbing influence of external agency. The injured tissues do not need to be 'stimulated' or treated with any mysterious 'specific'; ALL THAT THEY NEED IS TO BE LET ALONE. Nature will then take care of them: those which are weakened will recover, and those which have been deprived of vitality by the injury will serve as pabulum for their living neighbours. Now, of all external agencies the most injurious by far is putrefaction, and this, above all, we endeavour to exclude. But a substance employed with this object, if sufficiently potent to destroy the life of the putrefactive organisms, cannot fail to be abnormally stimulating to the exposed tissues; and these must be protected from its action if the wound is to progress exactly like a subcutaneous injury.

Our 'protective', then, should be a material unstimulating in its own substance, and impervious to carbolic acid. At the same time it must be insoluble in the discharges, and sufficiently supple to apply itself readily to the part. But it is by no means easy to find anything fulfilling all these conditions. Gutta-percha or caoutchouc, which naturally suggest themselves, transmit the acid from particle to particle of their substance with the utmost facility, and are utterly useless for this object. A metallic plate is quite impervious to the acid. But thin block-tin, which I once used, is too rigid, while tinfoil soon wears into holes. I have been lately trying a microscopically thin layer of metal, in the form in which you see it in this specimen. Cotton cloth, coated on one side with caoutchouc, is gilded on the caoutchouc side, and then covered with a film of india-rubber applied in solution. We have ascertained that the gold-leaf thus enclosed between two layers of caoutchouc spread on cloth wears thoroughly well; and, if I can get a manufacturer to enter into the thing, I have hopes of obtaining at last something like a perfect protective. And when this is attained, as the lac-plaster is quite trustworthy for excluding putrefaction, our treatment will yield to the full the beautiful results which theory indicates as possible.

There is one more point that must be mentioned with reference to the protective. It is essential that it should be itself antiseptic at the moment of its application, otherwise there would be a risk of its communicating septic particles. This object can be attained by covering it with an extremely thin film of some material soluble in water; so that when dipped into a watery solution of the acid it may be uniformly moistened with the antiseptic, but in so small a quantity as will be rapidly absorbed by the wound and by the skin, so as not to interfere to any material extent with the purely protective office of

the application. You will bear in mind that the protective is not designed to have any persistent antiseptic virtue; and that, like the wound at the first dressing, it must be freely overlapped at every point by the antiseptic plaster.

These principles will be found to apply whatever be the materials used for carrying out the antiseptic system. *An antiseptic to exclude putrefaction, with a protective to exclude the antiseptic, will by their joint action keep the wound free from abnormal stimulus.*

Though we have not yet got a perfect protective, that which we are now generally using answers very fairly, and has this advantage—that the materials for it can be obtained from any druggist's shop. The basis of it is the common oiled silk. I am indebted to my late house surgeon, Dr. Joseph Coats, now Pathologist to the Glasgow Royal Infirmary, for calling my attention to the fact that carbolic acid does not pass nearly so readily through oiled silk as through gutta-percha. But if oiled silk is dipped into a carbolic lotion before applying it, the watery fluid runs from the surface as from a duck's back, and there is risk of septic particles being depositied upon the dry parts, even during the rapid transfer from the vessel containing the lotion to the wound. I had reason to suspect that, in some cases of hollow wounds, putrefaction was actually brought about from this cause; and hence I was induced to abandon the oiled silk for a while. But of late I have had it coated with a soluble film, which entirely removes this objection. The oiled silk is brushed over with a mixture of one part of dextrine, two parts of powdered starch, and sixteen parts of cold watery solution of carbolic acid (1 to 20). The carbolic-acid solution is used rather than water, not for its antiseptic property, but because it makes the dextrine apply itself more readily to the oiled silk, and the granular starch is used for a similar purpose. The carbolic acid may be afterwards allowed to fly off without disadvantage; so that there is no need for keeping the protective, like the antiseptic plaster, in a close vessel. Oiled silk thus prepared becomes uniformly moistened when dipped in a watery solution of the acid, so that all risk of communicating putrefactive mischief along with it is avoided; and if it be used in two layers it opposes a pretty effectual barrier to carbolic acid, as is sufficiently illustrated by the progress of the present case.

On the day after the accident the cloths around the lac-plaster applied to the ankle, and even the pasteboard splint and its padding, were found soaked with bloody discharge. On the second day, when the dressings were again changed, the cloths presented only a stain corresponding to a few drachms of tinged serum; so that I thought it safe to allow two days to pass before the next dressing. I believe it to be best in all cases to change everything on the

day following the injury; because the effusion from the wound is then of a bloody character, and though the lac-plaster certainly sheds the discharge admirably, yet it is possible that a layer of clot may be lying beneath it, which might interfere with its antiseptic operation. But after the first day, sanguineous effusion having ceased, the interval between the times of dressing should be regulated by the amount of discharge to be anticipated; for the more copious it is, the sooner does it exhaust the carbolic acid in the plaster. The lac may happily be always trusted to retain enough of the acid for twenty-four hours, however free the discharge may be. If the stain on the cloths indicates an effusion of only a few drachms, the plaster may be safely left for two days. If the serous oozing be not more than a few minims, the interval may be extended in proportion to the smallness of the amount, till finally, when, as sometimes happens, the plaster is maintained as a precautionary measure though no discharge is present, it may be left for a week without losing its antiseptic virtue. When the interval between the dressings is thus prolonged, the pains taken during the first few days are rewarded by great saving of trouble, as well as by the satisfactory progress of the patient; and when the case is one of fracture, the avoidance of frequent disturbance of the limb is of course a matter of most material consequence.

At the next dressing, four days after the accident, the ankle presented an appearance which would have been impossible without antiseptic management. The hollow wound, about three inches long, and gaping about an inch, was still occupied by the original coagulum on a level with the surrounding skin; while the discharge of the last two days had caused only a serous stain of a few minims on the cloths. But this state of things was not merely the result of *antiseptic* treatment. It implied that our *protective*, also, was answering its purpose well. Had the antiseptic been acting directly on the wound, the discharge would have been much more considerable, and we should probably have already had a hollow sore with commencing suppuration. Here I cannot help observing that it seems to me strange that some who have not scrupled to criticize me with great severity should have taken so little trouble to ascertain what I have written on this subject. From the remarks made by some persons, you would imagine that I regard putrefaction as the sole cause of suppuration; whereas my treatment of abscess depends essentially upon the fact that the pus in the unopened cavity, being the result of the inflammatory stimulus without atmospheric influence, is free from putrefaction, so that it is needless to apply the antiseptic to the interior, all that is requisite being to provide exit for the discharge while guarding against the entrance of putrefactive fermentation. Again, from the statements of others you would suppose me to have

taught that, if you do but apply carbolic acid freely to a wound, you will prevent suppuration; whereas I have all along pointed out that carbolic acid, being a stimulating substance, will itself induce suppuration by long-continued action on the tissues.[1]

[The facts observed in developing the antiseptic system have thrown great light upon the causes which determine the occurrence of suppuration; and the subject is of such great practical importance that it may be well to take this opportunity of giving definite expression to the conclusions to which I have been led. It fell to my lot several years ago to establish, as the result of an experimental inquiry, that the tissues of the living body are liable to a temporary impairment or suspension of vital energy as the result of extreme irritation; and that this condition, which appears to be the essence of *intense* inflammation, may be brought about in two totally distinct ways—viz. either by the direct operation of a noxious agent upon the tissues, or indirectly through the medium of the nervous system.[2] The same law appears to hold with regard to the causes of the exaggerated but feeble cell-development which results from the continued action on the tissues of some abnormal stimulus in a less intense form, giving rise, according to its degree, to the various phenomena of inflammatory hypertrophy, granulation, and suppuration; the pus-cells being the extreme of excess of quantity and impairment of quality in the product of abnormally excited nutrition. Thus the causes of suppuration divide themselves into two great groups: first, those that operate through the nervous system, or, in other words, the inflammatory class, of which the common abscess presents a typical example; and, secondly, noxious agents or stimuli acting directly on the tissues. The latter group are, practically speaking, stimulating salts, or chemical stimuli. These are best studied in the behaviour of a healing ulcer under different kinds of treatment. Small granulating sores sometimes heal by scabbing; and when the surface is thus protected by a crust of dried discharge from the influence of external agency, there is no further effusion either of pus or serum. This is of itself sufficient evidence that granulations have no inherent tendency to form pus (or, as is sometimes absurdly said, to *secrete* it), but only do so when stimulated. The same thing is equally clearly shown by the well-known fact that two granulating surfaces will coalesce when placed in contact with each other. This coalescence would be impossible if they continued to suppurate; and their juxtaposition could oppose no obstacle to pus-formation if they had any innate disposition to it. But their mutual contact excludes the operation of external agents upon them; being freed from stimulation, they

[1] See pp. 6, 78 of this volume.

[2] 'On the Early Stages of Inflammation.'—*Phil. Trans.*, 1858 (reprinted in vol. i, p. 209).

cease to discharge; and they are then at liberty to coalesce. New examples of the same truth present themselves under the antiseptic system of treatment. The wall of an abscess is similar in nature to the granulations of a sore, and is often regarded as essentially 'pyogenic'. But if the abscess is opened antiseptically, the pyogenic membrane, being relieved from the inflammatory stimulus which the tension of the pus before induced, and being at the same time protected from the access of the stimulus of putrefaction, is left free from all disturbance, and never forms another drop of pus. But the most striking illustration I ever saw of the properties of granulations, when not subjected to stimulation, was presented by a case of compound fracture, in which an extensive portion of the shaft of the tibia had lost its vitality, and lay exposed in a large granulating sore. The granulations grew up and enclosed the dead bone, which, being prevented from putrefaction by the treatment employed, was destitute of the usual acrid properties of an exfoliation; so that the granulations, being not stimulated by it, not only formed no pus from the surface in contact with it, but gradually consumed the dead mass by absorption.[1]

The truth is, that so far from granulations having any inherent tendency to form pus-corpuscles, the imperfect tissue of which they consist is ever disposed to develop into higher forms as soon as it is left free from preternatural excitement. This is beautifully illustrated by the familiar phenomena of the healing ulcer. The granulations are still granulations—that is to say, possess still the same pathological structure, when covered by the pellicle of newly formed epidermis at the edge of the sore, as when they were exposed. But no sooner does the film of young epithelium protect the imperfect tissue from the influence of external stimulus than the rudimentary structure of the granulations immediately proceeds to develop into the more and more perfect fibrous tissue of the cicatrix.

It being, then, clearly understood that granulations form pus only when abnormally stimulated, we are in a position to estimate the effects of different agents upon them. The simplest case is when an antiseptic substance, like chloride of zinc or carbolic acid, is applied, suitably diluted, to a healthy granulating sore. Not the slightest redness of the surrounding skin, or any other indication of inflammatory disturbance, is produced; yet the granulations, so far as they are exposed to the influence of the stimulating liquid, are excited to superficial suppuration, but form no pus where they are protected from the stimulus by the pellicle of epidermis at the margin. Here, then, we have entire absence of the inflammatory stimulus; but the chemical stimulus of the pungent

[1] See p. 16 of this volume.

antiseptic salt urges the superficial cells of the granulations to develop pus-corpuscles.

If the sore is treated with water dressing, the serum first exuded putrefies in the lint, and the products of putrefaction, being acrid salts, cannot fail to stimulate the surface of the granulations ; and accordingly superficial suppuration is induced without any appearance of inflammation, just as under the influence of the antiseptic. Thus, in their effects upon a granulating sore, an antiseptic and a putrid dressing are alike : both excite superficial suppuration by direct chemical stimulation of the granulations. But in their operation on a recent wound there is this all-important difference between them, that the antiseptic stimulates only the surface to which it is applied, and every drop of discharge which it induces dilutes it and renders it less stimulating ; but putrefaction being a fermentation, the self-propagating ferment spreads throughout all the recesses of the wound, wherever extravasated blood, or serum, or portions of dead tissue afford nidus and pabulum for its development, and its products become more and more acrid the longer it continues in operation. Antiseptics, then, though they do produce suppuration when applied continuously to a recent wound, are superficial in their action and utterly trivial compared with the deep and virulent effects of putrefaction, which, indeed, often causes death by irritation and blood-poisoning before suppuration has had time to be established.

These conclusions may be exhibited in a diagrammatic form as follows :—

Causes of Suppuration.

Abnormal stimulation of the tissues,	A	Through excited nervous action	*Inflammatory.*
	B	From the direct action of stimulating salts	*a. Putrefactive.* *b. Antiseptic.*

This scheme, though not strictly exhaustive,[1] applies to almost all circumstances met with in surgery ; and it will be found to conduce to clearness to speak of suppuration as inflammatory, putrefactive, or antiseptic, according to the circumstances in which it occurs.[2]]

If the use of the protective be so advantageous, you may naturally inquire why I do not employ it at the first dressing. The reason is twofold. In the

[1] The group *a* ought to include the products of other ferments besides those of putrefaction. For I am satisfied that inodorous ferments sometimes occur in the animal fluids, and produce salts which stimulate to suppuration. Also viruses inducing suppuration are very probably of the same essential nature (ferments), though some at least are odourless, as in the case of erysipelas. Again, the group *b*, to be complete, should include salts which, though not the products of putrefaction, cannot be said to be antiseptic, such as dilute chloride of sodium, &c.

[2] Any special case, not falling under the scheme, may be called according to its special nature ; thus we may speak of erysipelatous suppuration, variolous suppuration, &c.

first place, there must necessarily be a considerable discharge of blood and serum during the first twenty-four hours, and hence this is the period in which there is greatest risk of putrefaction spreading into the wound, so that it does not seem wise to interpose anything that can interfere in the slightest degree with the antiseptic action of the dressing. And, in the second place, there is no chance of a suppurating sore being established by the direct action of the antiseptic upon the wound for a single day only. This leads me to speak of a condition of suppuration to which I have not before had occasion to advert—viz. the element of *time*. When the tissues are in a healthy state, no stimulus can induce them to suppurate. It appears that it is only when the tissues have been gradually degraded, under the influence of protracted abnormal stimulation, into the most imperfect of all tissues, which, when we see it at the surface of a sore, we term granulations, that they are in a condition, if further stimulated, to give birth to the still lower progeny of pus-corpuscles. In other words, granulation must precede suppuration, and it is a process which requires days for its completion.[1] Thus it is a familiar fact to all surgeons that a recent wound in healthy tissues does not suppurate for three or four days when subjected to ordinary treatment—that is to say, the stimulus of putrefying material must act for three or four days upon the tissues before it can induce them to suppurate; and when the first-formed pus is wiped from the wound, granulations may be seen upon the surface.

The same holds with regard to the inflammatory stimulus. Inflammation does not produce suppuration in a day. Whether acute or chronic, it must first degrade the tissues to granulations before it can occasion the formation of pus. This is well illustrated by a common boil, which is a limited inflammation of the cutis vera, so severe at the centre as to destroy the vitality of a portion of the tissue, and gradually shading off to the state of health in the vicinity. Here, though all possible degrees of intensity of inflammation are present, between the centre and the circumference, no pus is produced till some days have elapsed. Then the 'core separates', as it is said, and the slough is found detached from the neighbouring living tissues, and surrounded by a few drops of odourless pus. But when the slough and the pus are removed, the cavity in which they lay is seen to be lined with granulations. The inflammatory stimulus, like the putrefactive, had induced granulation as a preliminary to suppuration.

[1] An exception to this statement must be made for the case of the epithelium of some mucous membranes, the cells of which, originally of simple structure, soon form pus-corpuscles under slight abnormal stimulation. While thus adopting the language of the 'Cellular Pathology', elaborated by Virchow and others following the path first opened up by Goodsir, I may remark that my own experience has tended to convince me of the truth of that doctrine.

In the same way, an antiseptic must act for days upon a wound before it can convert it into a granulating sore liable to suppuration ; so that no harm is done by omitting the protective for the first twenty-four hours.

The other injuries in our patient have thus far proceeded as satisfactorily as that of the ankle. The four severe scalp-wounds were dressed on the day after the accident, and each was covered with protective before the cap of lac-plaster was reapplied. On the following day, the discharge to be seen on the cloth round the lac was so slight that I thought it safe to leave the head undisturbed for another day. The second dressing was witnessed by some of you just after last lecture. The discharge of the two days amounted to only a few minims of serum, and there was entire absence of redness, puffiness, or tenderness of the scalp. I removed the numerous sutures, each coming out as clean as when it was introduced ; and all the wounds seemed already completely healed, except a small superficial raw surface here and there.

The compound fracture into the elbow-joint, when last dressed, presented only a trace of serous discharge, so that I shall not think it needful to disturb it till five days shall have passed since that occasion.

The following remarks conclude the case :—

Before proceeding to relate the further progress of this case, I have to direct attention to another circumstance of great practical importance in the injury to the ankle. On the day after the accident it became apparent that the violence to which the part had been subjected had destroyed the vitality of portions of the integument, not only at the anterior margin of the wound, where a slough about half an inch in breadth existed, but also in detached patches at the outer aspect of the dorsum of the foot. Now, if any one of these dead pieces of skin had been left exposed to atmospheric influence, it would have putrefied ; and the putrefaction would in all probability have spread along the extravasated blood and serum in the subcutaneous tissue till it had reached the seat of fracture and the articulation, and all our antiseptic treatment of the wound would have proved nugatory. I once saw a case of compound fracture of the forearm, in which the antiseptic treatment had been pursued with thoroughly efficient means, but after the lapse of some days I was asked to look at the limb, in consequence of unsatisfactory appearances. I found the dressings applied perfectly correctly, and I had no reason to doubt that they had been so from the first ; but the wound, when exposed, emitted an offensive discharge. On investigation I found a small slough of the skin, about half an inch in diameter, situated some inches from the wound, and just beyond the limits to which the lac-plaster had been extended. The little slough had by

this time undergone softening from putrefaction, so that the nozzle of a syringe could be introduced through it ; and, on injecting some of the watery solution of carbolic acid, I found that it passed freely beneath the integument to the seat of fracture and to the external wound. Whether the skin had been thus extensively detached at the time of the accident, or whether the subcutaneous tissue had been simply loaded with extravasated blood, the spreading of the putrefactive fermentation from the slough exposed to the air was easily intelligible.

It is therefore essential that every isolated slough which may exist in the vicinity of a contused wound should be dressed antiseptically like the wound itself. But it may be asked, How is it possible to secure this at the time of the first dressing, seeing that there is nothing in the appearance of the skin in the first instance to indicate that vitality has been destroyed ? The simple rule for attaining the desired object is to let the antiseptic plaster first applied overlap the apparently uninjured skin far and wide in all directions. Then, on the following day, let the integument be carefully scrutinized, when any dead portions will be recognized by a dusky discoloration. Every such discoloured patch should then be dressed, as if it were a wound, with a piece of protective and well-overlapping lac-plaster. If the protective were omitted, the slough would acquire stimulating properties from the carbolic acid perpetually communicated to it by the lac-plaster, and would excite the neighbouring living parts to granulation and 'antiseptic suppuration'. But if efficiently protected from the antiseptic, as well as from putrefaction, the dead tissues will be absorbed and organized like the clots of blood, new living structures being formed at the expense of the effete but nutritious mass.

Such was the course pursued in the present case ; and, the oiled silk protective having been used in two, and sometimes three, layers, the results have approached very closely to those which are theoretically attainable. Some of the smaller portions of slough have been entirely removed by absorption, their place being taken by vascular new tissue. Five weeks after the accident, the large slough at the anterior margin of the wound had been considerably reduced in superficial extent, without the formation of any line of separation. What remained of it was of firm consistence, though of yellowish-white colour. In order to ascertain to what extent the process of organization and vascularization had advanced in it, I scratched its central part with the point of a sharp knife, and found that the little incision bled when I reached a depth not above half that of the cutis vera, whereas the original slough had undoubtedly involved, not only the entire cutis, but the subcutaneous fat. The mass of dead tissue, though superficially situated, being protected from the disturbing influence

of external agency, was undergoing the same kind of change as is experienced by parts deprived of vitality in the subcutaneous injury of a simple fracture.

The appearances of the wound itself presented an equally striking difference from those met with under ordinary treatment. Even at that late period, five weeks after the accident, the original clot was still to be seen, of an orange-brown colour, on a level with the surrounding skin, but greatly diminished by contraction and also by cicatrization, epidermic formation having advanced considerably from all parts of the margin of the wound, except anteriorly, where the slough was present. An open sore healing by cicatrization without suppuration, or even granulation, is something new in the history of surgery, though exactly what might have been expected from what we know of healing by scabbing. At the lower extremity of the wound the new and vascular tissue which had been formed by organization of the clot was slightly more prominent than the rest, and had somewhat the characters of granulations covered with epidermis. But not a trace of pus had been produced. On the occasion when these observations were made, eight days had been allowed to pass since the last dressing, and in order to estimate accurately the quantity and quality of the discharge, I removed the lac-plaster without injecting any watery solution beneath it, knowing that at this late period no risk would be incurred by free exposure of the wound. The bandage outside the plaster being free from stain, the whole discharge of eight days had accumulated beneath the impermeable layer of lac, and consisted only of about two minims of white but thin fluid, together with some desquamated epidermis. I subjected the milky liquid to microscopic examination, and found that the opaque element was composed exclusively of epidermic scales.

The vascularization of the clot, like that of the sloughs, had been advancing from below as well as round the margins. Fifteen days after the accident I cut into the central part of the then chocolate-coloured coagulum, under the protection of a stream of watery solution of carbolic acid, and found that it did not bleed, though the knife penetrated about a quarter of an inch. But on a repetition of the experiment twelve days later, blood oozed up from an incision carried to only about the depth of an eighth of an inch.

The process of organization of clots and sloughs thus observed in an external wound, though of the same essential nature as that which occurs in subcutaneous injuries, was undoubtedly retarded by a certain degree of abnormal stimulation inseparable from the method of treatment. For, besides the fact that the protective was not perfect—i.e. not absolutely impermeable to the carbolic acid furnished by the lac-plaster—the clot and sloughs were more or less soaked with the antiseptic lotion every time the dressings were changed; and though the

acid is soon diffused and carried away by the circulation, this circumstance necessarily operated as a disturbing cause. Hence the rate of healing will be more rapid in proportion to the efficiency of the protective, and also to the length of the intervals that can be allowed to pass between the dressings consistently with security against putrefaction. In the present case, the period between the dressings was extended as the discharge diminished, and it may be worth while to mention the successive intervals. From the date of the accident they were as follows: one day; one day; two days; three days; three days; five days; five days; seven days; and finally eight days; bringing the time up to five weeks from the receipt of the injury. But I am not prepared to recommend a longer time than a week, and even that only when the discharge is practically *nil.* Indeed, in our patient, putrefaction did take place in the period following that of eight days. I had intended allowing another week to pass before meddling with the limb, but at the close of the sixth day my house surgeon informed me that the patient had got up two days before, without leave, and had made his way, on chairs as crutches, to the fire, a distance of several yards; and, further, that there was an appearance of a stain upon the bandage. I therefore exposed the limb, and found that the discharge was considerably greater (amounting to perhaps half a drachm), fetid, and, for the first time since the accident, unmistakably puriform. The dressings removed on the last occasion had been perfectly odourless; and the most probable explanation seemed to be, that the vascular engorgement of the limb occasioned by the dependent posture had induced an unusual exudation of serum from the wound, and that this circumstance, combined perhaps with some movements of the foot, had proved too much for the antiseptic power of the lac-plaster at that period after its application. Happily the occurrence was of no consequence, as the wound was practically superficial, and beyond the reach of danger from putrefaction. But it may serve as a warning. And it must ever be borne in mind that, in the earlier stages of such a case as this, where the avoidance of putrefaction may be a matter of life and death, it is better to err on the side of dressing too often, rather than too seldom.

The putrefaction had evidently occurred quite recently, for the clot and sloughs were not yet detached. I clipped away most of the slough, and scraped off the clot till I got down to bleeding tissue, and, with the view of correcting the putrefaction in such portions of dead material as remained, I treated the sore with a strong solution of carbolic acid in spirit of wine (one part to five), and, having washed the skin around with watery solution, applied lac-plaster, omitting the protective. Next day, however, the putrefaction was reproduced; showing that the antiseptic employed had not thoroughly penetrated the adher-

ing portions of slough. Having at hand some saturated solution of chlorine gas in water (the liquor chlori of the *British Pharmacopoeia*), I applied it freely to the sore and also to the surrounding integument, and then dressed with protective dipped in chlorine water and covered with overlapping lac, as formerly. On the following day the sore was destitute of odour of any kind, while the discharge was greatly reduced. For the future it will be treated as a superficial ulcer.

With regard to the injury to the ankle, it only remains to be mentioned that, at the present time, six weeks after the accident, the fracture of the internal malleolus has united firmly, and the foot is in good position ; while the patient has already considerable movement of the ankle-joint.

The four severe scalp-wounds—three of which, it will be remembered, involved exposure and injury of the bone—healed completely, without the formation of a drop of pus. And it was an interesting circumstance that, on the removal of some scabs, one of the silk sutures, which had been accidentally left, was found still securely in its place, three weeks after its introduction, and came away clean and dry, like a metallic stitch.

The compound fracture into the elbow-joint also healed without any suppuration. Five weeks after the receipt of the injury the splint was removed. The broken olecranon was found firmly united, and the patient has now free motion of the articulation.

Edinburgh, March 26, 1870.

FURTHER EVIDENCE REGARDING THE EFFECTS OF THE ANTISEPTIC SYSTEM OF TREATMENT UPON THE SALUBRITY OF A SURGICAL HOSPITAL

[*Lancet*, 1870, vol. ii, p. 287.]

In the early part of this year a paper was published in the *Lancet*,[1] in which I recorded the general results of my practice in the Glasgow Infirmary during three years in which the antiseptic system of treatment had been carried out, as compared with my previous experience in the same institution with ordinary management of the cases. It was there shown that the strict enforcement of the antiseptic principle had been accompanied by a most striking change in the salubrity of the wards under my care, which had been converted from some of the most unhealthy in the kingdom into models of healthiness; and I ventured, in conclusion, to make the following remark: 'Considering the circumstances of those wards, it seems hardly too much to expect that the same beneficent change which passed over them will take place in all surgical hospitals when the principle shall be similarly recognized and acted on by the profession generally.' I have now the pleasure of announcing an instance of the fulfilment of this anticipation, as related in the following letter from Dr. Saxtorph, Professor of Clinical Surgery in the University of Copenhagen.

'My dear Sir.—It is now nearly a year since I left Glasgow, where I had the opportunity of seeing how the antiseptic treatment of wounds is to be carried out. Every surgeon who has seen the remarkable results of this treatment must feel it his duty to imitate you, and dress the wounds after your principles. I therefore, as soon as I came home, adopted your method, and have used it now continually since that time; and I am happy to say that, although I have not generally succeeded in obtaining complete primary union, except in smaller wounds, still the treatment has proved in other respects extremely satisfactory. The hospital to which I am appointed head surgeon (the Frederik's Hospital) is a very old building—in fact, it is now much more than a hundred years old—and it contains about 350 medical and surgical beds. In the surgical wards I have room for about 150 patients; but the usual number during the winter has varied from 100 to 130. Formerly there used to be every year several cases of death caused by hospital diseases, especially by pyaemia; sometimes arising from the most trivial injuries. Now, I have had the satisfaction that not a single case of pyaemia has occurred since I came home last year, which result is certainly owing to the introduction of your antiseptic treatment. But

[1] See p. 123 of this volume.

it must be clear to any surgeon who has adopted your method that unless you take the greatest precautions in *every* dressing till the wound is either healed or filled up with granulations, you will never see the excellent effects of this treatment. It certainly takes much longer time, and demands much greater precautions, than any other dressing ; but the reward is certain, and it is a great satisfaction to know that the good result of many operations almost entirely depends upon your dressing of the wound. As an instance of this I may mention the following case : A man came to me with a foreign body in the left knee. I thought it to be, not a loose cartilage, but a fragment of the tibia, loosened by the kick of a horse eight years ago. It was situated behind the ligamentum patellae, was a little movable, and grated very distinctly as two osseous surfaces would do. I made a large incision on the outer side of the capsule and tried to extract it, but the surfaces were so much entangled in each other that I was obliged to use my finger and different hooks and forceps before I got it out. The operation lasted certainly a quarter of an hour, and during the whole time I poured a stream of carbolic solution over the wound. Having extracted it at last, it proved to be really a part of the head of the tibia with its cartilaginous surface on it, and of the size of a small walnut. I treated antiseptically, and the wound closed without any suppuration in the joint. All the compound fractures which I had to deal with last year, some of them very severe ones, have healed without the least suppuration in the fracture itself, and the consolidation did not take much longer time than in a simple fracture. All the amputations of this year have recovered. There has certainly been some suppuration, but it never became profuse, and I never observed any putrefaction. I feel so much indebted to you for what I have learnt in seeing you employing the antiseptic dressing, that I thought it my duty to let you know how things went on in my hospital practice ; and I am happy to say that I never tried any innovation which answered so admirably as this treatment of wounds.—Believe me, my dear Sir, ever yours,

‘ SAXTORPH.

‘July 18, 1870.’

It may seem strange that results like these should have been obtained in Copenhagen, when so little approach to them has yet been made in the capital of England. The fact, however, is not difficult to explain. Want of success in many quarters has not arisen from any unwillingness to try a new mode of practice. On the contrary, the publication of my first papers was followed by a very general employment of the material which I happened to select for carrying out the treatment, and which, unfortunately for the principle involved, was then little known in British surgery, so that the striking results which were recorded were too often attributed to some specific virtue in the agent. The antiseptic system does not owe its efficacy to any such cause, nor can it be taught by any rule of thumb. One rule, indeed, there is of universal application—namely this : *whatever be the antiseptic means employed* (and they may be very various), *use them so as to render impossible the existence of a living septic organism in the part concerned.* But the carrying out of this rule implies a con-

viction of the truth of the germ theory of putrefaction, which, unfortunately, is in this country the subject of doubts such as I confess surprise me, considering the character of the evidence which has been adduced in support of it. Yet, without this guiding principle, many parts of the treatment would be unmeaning ; and the surgeon, even if he should attempt the servile imitation of a practice which he did not understand, would be constantly liable to deviate from the proper course in some apparently trivial but essential detail, and then, ignorant of his own mistake, would attribute the bad result to imperfection of the method. For my own part, I find that, in order to approach more and more to uniform success, it is necessary to act ever more strictly in accordance with the dictates of the germ theory. Failure on the part of those who doubt or disbelieve it is therefore only what I should expect.

Another great cause of failure undoubtedly is, the careful attention necessary in order to exclude, from first to last, the subtle putrefactive organisms that people the atmosphere and form part of the dust which adheres to all exposed objects. The germ theory, while it furnishes the clue to success, affords ample explanation of failure. I believe I do my professional brethren in Britain no more than justice when I say that if they felt anything like the assurance expressed in Professor Saxtorph's words, 'the reward is certain,' they would not grudge a greater degree of trouble than the antiseptic treatment demands. And, in truth, when once a surgeon has become thoroughly initiated into the practice, it is in most cases a saving of trouble. Thus I have at present a patient about to leave the infirmary three weeks after the removal of the entire mamma for scirrhus, all the axillary glands having been at the same time cleared out after division of both the pectoral muscles, so as to permit the shoulder to be thrown back and the axilla freely exposed, as is done in the dissecting-room—a practice which I have for some years adopted where the lymphatic glands are affected in that disease. In this case a great deal of care was certainly required for the first few days ; but after a week the dressings were only changed once in three days, and when a fortnight had elapsed, cicatrization being almost perfect, a week was allowed to pass without any interference. Hence, on the whole, the labour was considerably less than with ordinary treatment, and a very much greater amount of pains would have been amply repaid by the beautiful linear cicatrix, formed without the occurrence of one drop of pus, and without any serious constitutional disturbance. This, however, was an instance in which an unusual degree of care was requisite ; for the axilla is one of the most difficult situations in the body to guard antiseptically, and I have only myself learnt quite recently the art of doing this, as I believe, with security. But in most cases the details of the treatment are not troublesome to execute

by any one accustomed to them ; yet they nevertheless require at first earnest practical study until their employment has become habitual and instinctive. It is therefore not to be wondered at that surgeons endeavouring to carry out the treatment without having seen it in operation, and only half persuaded of the importance of the object to be attained, should fail time after time, and throw up the attempt in disgust. Professor Saxtorph, on the other hand, having observed the effects of the antiseptic treatment, and appreciated its importance, spent a considerable time in carefully watching it in operation, and then set to work in right good earnest to carry it out ; and, as he believes in the germ theory of putrefaction, it is not surprising that sound principle and careful practice should have been crowned with the success which he has related.

I had not intended to have published anything regarding the general condition of my wards in Edinburgh till a longer period should have elapsed. But in connexion with Professor Saxtorph's letter, I may state that, having now been in charge of fifty beds for nine months in the Royal Infirmary here, I have as yet had no instance of pyaemia, although many cases have been admitted in which it might, under ordinary treatment, have been apprehended, such as compound fractures, amputations in the lower limb, and extensive gouging operations upon bone. Hospital gangrene also has been entirely absent. Though several cases of ulcers of long standing have been under treatment, there has never been any appearance of greyness of the surface to indicate even the mildest form of the disease.

Two cases of superficial erysipelas occurred in December ; but these seemed to me attributable to cold rather than to any poisonous condition of the atmosphere. In my former paper on this subject I mentioned a case[1] in which erysipelas appeared in a stump after amputation of a leg, long after the patient had left the Glasgow Infirmary with the wound entirely cicatrized ; and I remarked upon the interest of that case as occupying an intermediate position between traumatic and idiopathic erysipelas, implying that local irritation of such trivial nature as that of a contracting cicatrix might determine the occurrence of the complaint in a person predisposed to it constitutionally. We know also that exposure to cold is the most common exciting cause of the idiopathic form of the disease, which is entirely independent of any unhealthy state of the air. It therefore seems not unreasonable to suppose that where the local irritation of a wound coexists with a chill, traumatic erysipelatous inflammation may become developed in some persons in a perfectly pure atmosphere ; and such seemed the most probable explanation of the two cases to which I am now

[1] See p. 133 of this volume.

referring. One of them was a man above the middle period of life, in whom I had performed amputation at the knee-joint. Five days after the operation, the discharge amounting to only a few minims of serum in the twenty-four hours, and the patient being free from constitutional symptoms, I thought him a favourable subject for illustrating the antiseptic dressing of a stump before the clinical class. Accordingly I had him taken into the theatre, and dressed him there; and, not thinking how time was passing, I left the stump covered only with a piece of calico soaked with cold watery solution of carbolic acid while I discussed at considerable length the mode of procedure. It happened to be one of the coldest days of that severe winter, and it afterwards occurred to me that I had been guilty of imprudence in exposing the stump so long. Next day he complained of not feeling so well, and the skin near the wound exhibited the commencement of an erysipelatous blush, which spread some distance up the trunk before it finally subsided. The other case was one of removal of the mamma for scirrhus. In changing the dressings the exposed surface of the chest was syringed with the cold watery solution of carbolic acid, and, in that very cold weather, a chill was certainly not unlikely to occur from such treatment. Here also a blush of redness appeared near the wound, and, though it was only superficial and did not spread far, it was unmistakably erysipelatous. Taking this view of the cause of the complaint in these two cases, I adopted the simple expedient of making the 1 to 40 watery solution of carbolic acid by mixing that of the strength 1 to 20 with an equal quantity of hot water, so as to make a warm lotion; and during the seven months in which this plan has been pursued we have had no more appearance of erysipelas.

Thus my wards, although by no means models, as regards their principle of construction or the space allowed between the beds, appear perfectly free from any liability to hospital diseases.

Edinburgh, July 22, 1870.

A METHOD OF ANTISEPTIC TREATMENT APPLICABLE TO WOUNDED SOLDIERS IN THE PRESENT WAR

[*British Medical Journal*, 1870, vol. ii, p. 243.]

Having been requested to furnish some rules for the antiseptic treatment of wounded soldiers in the present war, I venture to suggest the following plan, in the hope that it will combine efficiency with the simplicity and facility of execution essential under such circumstances.

Wash the wound thoroughly, and also the surrounding skin, with a saturated solution of crystallized carbolic (phenic) acid in water, one part of the acid to twenty of water, introducing the fluid by means of a syringe, and manipulating the parts freely so as to cause the lotion to penetrate into all the interstices of the wound; and at the same time squeeze out such clots of blood as it may contain. The fluid should be introduced repeatedly to ensure its thorough penetration. Tie any bleeding vessels with properly prepared antiseptic catgut, cutting off the ends of the thread near the knot. If the surgeon do not possess this article, the arteries should, if possible, be secured by torsion; but for the sake of cases in which a ligature would be absolutely indispensable, some silk or linen thread should be kept steeping in a strong oily solution of carbolic acid, or, if very fine silk be used, it may be rendered antiseptic by steeping for a few minutes in the watery solution. When silk or linen is employed, the ends of the ligatures should be left projecting at the wound. While the antiseptic lotion is in the wound, extract if possible any foreign material that may have been introduced, such as a bullet or a portion of the patient's clothes; and if any spicula of bone exist entirely detached from the soft parts, remove such as can be readily reached, disregarding those which are of very small size or inconvenient of access.[1] Then place upon the wound two or three layers of oiled silk smeared on both sides with a solution of carbolic acid in five parts of any of the fixed oils—olive, almond, linseed, &c.—the oiled silk being made large enough to cover the raw surface completely and slightly overlap the surrounding skin. Next apply, without loss of time, lint, charpie, or cloth (linen

[1] Gunshot-wounds should not be stitched; but, where sutures are required, silk, steeped in oily solution of carbolic acid, will answer sufficiently well. After the introduction of the last stitch, distend the wound once more with the watery solution, by means of the syringe, and then continue the dressing, as in the text.

or cotton), well steeped in the oily solution of the acid, the cloth or lint being folded sufficiently to produce a layer at least a quarter of an inch in thickness, and extending a considerable distance, say three inches, beyond the oiled silk in all directions, the outer layer being made somewhat larger than the rest, so that the margin of the mass of cloth may be thin. Cover the oily cloth with a piece of thin gutta-percha tissue sufficiently large to overlap it on all sides by an inch or more, and retain it securely in position by a roller steeped in the antiseptic oil. Round this again wrap a still larger piece of folded cloth, say a folded towel, also steeped in the oily solution of carbolic acid, and cover it with a piece of oiled silk or gutta-percha.

With a view to the intelligent application of this dressing, it will be well to state briefly its *rationale*. The watery solution is applied in order to destroy once for all any septic particles that may have been introduced into the wound ; and the oily solution is employed to prevent the spread of putrefactive fermentation into the wound from without. The oiled silk, which is but slightly permeable to carbolic acid, protects the raw surface from the irritation of the acid in the oily cloth, and permits it to heal as under a scab. But though the ultimate office of the oiled silk is to protect the wound from the irritation of the antiseptic, it must itself be antiseptic at the time of application, and is therefore smeared with the oil, which in the course of no long time loses its carbolic acid by diffusion into the wound beneath. The substantial and widely extending oily cloth serves as a store of the antiseptic ; but the bloody and serous discharge soaking into the porous cloth tends to wash away the oil and deprive the dressing of its antiseptic character ; hence the necessity for the gutta-percha, which prevents the discharge from making its way directly outwards from the wound, and so establishing a road for the penetration of putrefaction inwards. At the same time the gutta-percha, though impermeable to watery or oily fluid, being readily permeated by carbolic acid, permits the antiseptic ingredient to pass in through it from the outer cloth and act upon the discharge that flows out beneath the overlapping margins of the gutta-percha. The outer cloth is intended to be changed as occasion may require, in order to keep up the supply of the antiseptic, while the gutta-percha and all beneath it constitute a more permanent application. The layer of gutta-percha or oiled silk outside the external cloth is to prevent the oil in that cloth from being wasted by soaking out into the surrounding articles of clothing, &c. ; or, still worse, neutralized chemically by the penetration inwards of putrid blood or other discharges from the ambulance-wagon or bedding. The circumferential part of the deeper cloth will, in consequence of its thinness, be kept completely antiseptic by the carbolic acid which passes inwards through the gutta-percha,

while the deeper layers of the thicker portion over the wound will probably in a few days be destitute of antiseptic, and therefore of stimulating, properties; hence the oiled silk, though desirable in order to ensure the absence of 'antiseptic suppuration', is by no means an essential part of the treatment, and if none of it be at hand the procedure may in other respects be conducted in the same way without it. Again, if the surgeon have no gutta-percha at his disposal, the risk that would otherwise arise from the permeability of the dressing may be overcome by frequently changing an external antiseptic cloth, or by treating its surface every few hours with the antiseptic oil.

The changing of the outer cloth will require care in order to avoid raising the edge of the gutta-percha along with it, and so admitting septic air towards the wound. It may be done with perfect security by having the cloth consist of two parts, one covering each half of the gutta-percha, and, as one half is raised, throwing a stream of watery solution (1 to 40) with a syringe upon the margin of the gutta-percha, a fresh oiled cloth being at once applied before the other portion of the former cloth is removed. If sufficient time cannot be spared for changing the outer cloth in this careful manner, it will be better for the surgeon to content himself with pouring fresh oily solution upon the exterior of the cloth without disturbing it, taking care that the oil enter well beneath its margins. I would advise that this should be done in preference where a large number of wounded have to be treated by one surgeon.

The strong oily solution (1 to 5) would irritate the skin if used continuously: after the first dressing a solution of half the strength should be employed, and after a few days it may be reduced to 1 to 20 if excoriation should occur.

The times of changing the outer cloth, or treating it with fresh oil, should be in accordance with the amount of discharge. During the first twenty-four hours the effusion of blood and serum is necessarily profuse, and it will be well that fresh oil be applied to the outer cloth within twelve hours of the first dressing, or even in six hours if there should be unusual oozing. On the second day, also, in the case of a large wound, two dressings in the twenty-four hours will be desirable. After this, if all go well, the discharge will diminish quickly, and a daily renewal of the antiseptic supply will be sufficient; and when five or six days have passed, to apply the oil once in two days will be all that will be required. This, however, should be continued after discharge has ceased entirely, till sufficient time has passed to ensure that the wound has healed by scabbing, or at least has been converted into a superficial sore.

The earlier the case comes under treatment the greater will be the prospect of success, but even after the lapse of thirty-six hours it need not be altogether despaired of.

In the case of compound fractures, the essential objects of the treatment may be attained by using splints constructed of stout iron wire bent into the form of the margin of a lateral splint, and strengthened by cross-pieces here and there. Such splints can be readily extemporized by the surgeon himself, by help of two pairs of wire-forceps. The splints should be applied one at each side of the limb, without any padding opposite the seat of injury except the dressing above described, but padded elsewhere with any suitable soft material, an interval being left between such padding and the dressing. The outer layer of oiled-silk or gutta-percha should be applied outside the splints, so that all that will be requisite in order to apply oil to the outer cloth will be to take off the oiled silk with its retaining bandage, and pour on the oil through the ample intervals between the wires. Or the splints might be applied immediately external to the bandage that retains the deeper layer of gutta-percha, leaving the outer cloth to be wrapped round external to the splints, cotton or charpie imbued with the antiseptic oil being tucked in under the splints to keep the margins of the gutta-percha in apposition with the limb, the cotton being changed as often as the cloth itself.

For the sake of the general healthiness of the atmosphere of the crowded military hospitals, it is extremely desirable that even superficial granulating sores should be treated antiseptically. This may be done consistently with rapid healing by washing the sore with watery solution of carbolic acid (one to twenty), and covering it with two or three layers of oiled silk smeared with the oily solution (one to twenty), with well-overlapping folded cloth steeped in similar oil, and over all a piece of gutta-percha tissue and bandage.

I have suggested in the above method the employment of such materials as are likely to be accessible to the surgeons of both armies. Other means exist, in some respects very superior. But the supply of these is at present limited, and those who possess them probably understand their use.

ON A CASE ILLUSTRATING THE PRESENT ASPECT OF THE ANTISEPTIC TREATMENT IN SURGERY

[*British Medical Journal*, 1871, vol. i, p. 30.]

A YOUNG man, eighteen years of age, was lately admitted under my care in the Royal Infirmary on account of impaired usefulness of the right arm, resulting from an accident which befell him three months previously, when the handle of a winch, revolving with great rapidity, struck the limb at the posterior aspect, about three inches below the elbow, breaking the ulna and dislocating the upper end of the radius forwards, the lower ends of the bones of the forearm being tilted backwards to a corresponding degree. He at once sought medical aid; but, strange to say, the nature of the injury was not recognized, and the result was that when I saw him the fragments of the ulna were firmly united at an obtuse angle with each other; a marked depression existing posteriorly over the seat of fracture, while the head of the radius formed a prominence at the anterior and outer aspect of the joint, being securely maintained in its abnormal position through the connexion of the other end of the bone with the lower end of the ulna. The elbow could not be flexed beyond a right angle, so that he could not put his fingers to his mouth; and, although the hand could be rotated passively, he was quite unable himself to execute pronation or supination. He also complained that the limb was so weak that he could not lift any heavy object from the ground, and expressed great desire to have this faulty state of matters rectified.

It was plain that before an attempt at reduction of the dislocated radius could be made with any chance of success, it would be necessary to break again the united ulna. But, considering the length of time that had passed since the accident, and the slightness of the leverage that could be obtained upon the seat of fracture so near the elbow, it seemed hardly likely that this object could be attained without a cutting operation. And even supposing the bone to give way, I felt it very doubtful whether the dislocation could even then be reduced, both on account of its long duration and because the angular form which the ulna had assumed implied a shortening of the forearm, which at that late period necessarily affected all its textures. On the other hand, there could be little doubt that, if the ulna were exposed and divided, and if, further, the head of the radius were removed, the limb could be at once restored to its proper

form. But to do this would be to make voluntarily a compound fracture of the ulna and a compound dislocation of the elbow-joint—a procedure which, under ordinary treatment, I should have regarded as unjustifiable. But with the means now at our disposal of guarding against the mischievous influence of external agents upon wounds, I believed that these two operations could be performed without any chance of mischief resulting. Accordingly, at a clinical lecture on December 12, 1870, having explained the aspect of the case, and having failed to rebreak the ulna by very forcible measures under chloroform, I first washed the skin of the forearm and elbow with 1 to 20 watery solution of carbolic acid, to destroy all putrefactive particles in the epidermis and hair-follicles, and then made a longitudinal incision about two inches long over the back of the ulna where it had been broken, while an assistant threw over the part a cloud of spray of 1 to 40 carbolic lotion by means of Richardson's apparatus ; and, having sufficiently detached with the knife the muscles from the bone, and ascertaining precisely with the finger the situation of the callus, I inserted the blades of a pair of strong bone-pliers, smeared with an oily solution of the acid (1 to 10), and, cutting through the bone, used the pliers as a powerful lever to wrench the fragments sufficiently apart, and detach them enough from surrounding soft parts to ensure free mobility, the antiseptic spray being meanwhile constantly maintained. A sponge wrung out of 1 to 40 watery solution having then been bandaged upon the wound, I made an attempt to reduce the dislocation of the radius ; but, meeting with the failure I had anticipated, I at once cut down upon its head in a cloud of spray, and removed it by nipping through its neck with the pliers, the blades of which had been again smeared with the oil. A folded cloth dipped in the watery solution having been laid upon the wound, I had the satisfaction of finding the forearm assume, under moderate extension and coaptation, a perfectly normal shape. The limb was then enveloped in lac-plaster from the middle of the arm to the lower part of the forearm, the sponge and cloth having been previously removed under the spray, the wounds being left unstitched, to secure complete absence of tension from accumulating blood or serum. Cloths to absorb discharge, and a roller smoothly applied so as to adapt the plaster well to the limb, and a pair of Gooch's splints, anterior and posterior, with a special pad in front over the seat of fracture, completed the dressing, the elbow being kept at a right angle.

Next day, the dressings were entirely changed, when it was found that a good deal of blood and serum had oozed into the cloths. The lac-plaster was cut up with scissors along a line distant from the wounds ; and, as it was raised from the limb, the spray of 1 to 40 lotion was made to play beneath it. The gaping wounds were found filled with blood-clot, while the limb was free

from swelling, redness, or tenderness. The limb having been washed from bloody stain with a cloth dipped in 1 to 40 lotion, while the wounds were kept covered with bits of rag wrung out of the same, oiled-silk ' protective ',[1] dipped in the lotion to give it a temporary antiseptic film, was placed upon each wound to protect it from the stimulating action of the acid in the lac-plaster, which was then wrapped round the limb in two layers, extending several inches beyond the 'protective' in every direction, after which the splints were reapplied as before.

This dressing was left unchanged for two days, after which the patient was again dressed in a precisely similar manner before the clinical class, walking into the theatre and upstairs again to his bed just like a person affected with a simple fracture or dislocation. His pulse was 70, his temperature 98·2, and he was entirely free from pain. The stain on the cloths corresponded to about half a drachm of bloody serum ; the clots remained unaltered in appearance in the wounds, and the limb in the vicinity had still a perfectly natural aspect. Feeling sure that the discharge would now be very slight in amount, I left this dressing untouched till the following lecture, four days later, or just one week after the operation, when the wounds were again exposed before the class. All remained the same, except that while there was no pus, and merely a stain corresponding to a few minims of serum as the product of both wounds for four days, the blood-clots had been extensively converted into vascular tissue, while some portions yet unvascularized had assumed a grey or yellowish colour, and in both wounds there was a broad cicatrizing margin. Healing, though under a moist dressing, was going on as under a scab ; or, in other words, putrefaction being excluded by means of an efficient antiseptic guard, while the exposed tissues were protected from the action of the antiseptic salt by the interposition of a layer of unstimulating material, the disturbing influence of external agency was avoided, and we attained very closely to the conditions of a subcutaneous injury.

On this occasion, instead of the lac-plaster, a folded muslin cloth, of open texture, imbued with a mixture of paraffin, resin, and carbolic acid, was employed to combine the functions of the lac-plaster and absorbing cloth. Hitherto I have been opposed to porous antiseptic dressings, having observed that, when in the form of lint steeped in an oily solution of carbolic acid, the discharge, if at all free, washed out the antiseptic liquid from among the neutral fibres, and opened a way for the penetration of putrefaction. But, having heard

[1] This protective is made by varnishing oiled silk on both surfaces with copal varnish, which renders it considerably less permeable to carbolic acid, and when dry it is brushed over with a mixture of starch and dextrine to give it a film of material soluble in water, so that it becomes uniformly moistened when dipped into the antiseptic lotion. When it is not at hand, common oiled silk may be used as a substitute for it, if smeared with an oily solution of carbolic acid, and used in two layers to make up for its inferior efficiency. [See also pp. 184–5 of this volume.]

reports from various quarters of the efficacy of oakum, I have lately put it to the test with granulating sores, where, if it should happen to fail, no mischief would result, and I have found it more than answer my expectations. The reason for its superiority over oily cloths is readily intelligible. Each fibre of the oakum is imbued with an insoluble vehicle of the antiseptic ; so that the discharge in passing among the fibres cannot wash out the agent any more than it can when flowing beneath the lac-plaster, to a narrow strip of which an individual oakum fibre is fairly comparable. I may remark as worthy of notice by those who still cling to the idea that carbolic acid has some unknown virtue distinct from its antiseptic property, that oakum contains none of that substance, but creosote and probably other antiseptic hydro-carbons, the effects of which in preserving smoked meat are familiar.

Oakum not only proved efficient antiseptically, but presented several advantages over lac-plaster. When the latter is left as a dressing for several days together, the discharge, even though small in amount, soaking into the absorbing cloths, loses the carbolic acid it had received from the plaster, and, putrefying from day to day, assumes an acrid character, and sometimes produces most troublesome irritation of the skin. This is, of course, avoided by the oakum. Again, the lac-plaster being quite impermeable to watery fluid, keeps the skin beneath it moist, and, in fact, covered with a weak watery solution of carbolic acid, which, I suspect, insinuates itself, more or less, beneath the protective, and maintains a slight stimulating influence upon the parts beneath into it. But oakum, draining away the discharge as fast as it is effused, avoids this source of disturbance. The result is, that if a granulating sore is thoroughly washed with an antiseptic lotion and covered with 'protective' and a well-overlapping mass of oakum secured with a bandage, a dressing is provided which nearly approaches the ideal I have long had in view. For, as granulations do not form pus or even exude serum except when stimulated, a persistent antiseptic, combined with an efficient protective, should constitute a more or less permanent dressing under which discharge should cease and cicatrization proceed with great rapidity. Accordingly, ulcers of the leg treated in this way have been found, when exposed after the lapse of several days, either entirely healed or greatly advanced in the process, while the moisture beneath the protective has been of a serous character and the discharge collected in the oakum comparatively small in amount. Lastly, the lac-plaster has this further disadvantage from the moisture beneath it, that it prevents efficient strapping in cases that require it. But under oakum an adhesive plaster retains its hold as well as under dry lint.[1]

[1] Antiseptic adhesive plaster is readily improvised by dipping ordinary strapping in a hot solution

But while oakum has these great advantages, it is disagreeable to many persons from its strong tarry smell; and I have been lately endeavouring to apply the oakum principle in some shape free from this objection. Oakum consists of the detached fibres of old ropes which had been treated with Stockholm tar, among the constituents of which is common resin. I happened to notice, several years ago, that resin holds carbolic acid with remarkable tenacity, so that if one part of the latter be mixed by melting with five of the former, the glutinous mixture which results on cooling communicates only a slight warm taste to the tongue, though containing so large a proportion of the pungent antiseptic. But this material is of itself too sticky for the purpose, and resin is, besides, somewhat irritating to delicate skins. Paraffin, another constituent of tar, is remarkable for its entire absence of adhesiveness, as well as for its perfect blandness; but when pure, though it may be mingled with carbolic acid in the melted state, it separates entirely on cooling. If, however, the three ingredients be melted together, the resin, though intimately blending with the paraffin, still retains its hold upon the acid after cooling, and by a proper proportion between them, a product is obtained which, while intermediate in physical properties between the glutinous resin and the powdery paraffin, is unirritating to the most sensitive skin and highly retentive of the acid, while almost destitute of odour.[1]

Cheap muslin gauze dipped in the melted mass, and well wrung or pressed while hot, is an elegant and convenient form of modified oakum. It should be folded into about eight layers; and in order to prevent the discharge from soaking too directly through it, a piece of thin gutta-percha tissue may be placed beneath the outer layer to guide the fluid towards the edge of the cloth.

Such was the dressing employed a week after the operation. Three days later, the wounds were found still healing rapidly without suppuration, and, on rotation of the hand, the end of the radius was felt moving in its proper place, while the ulna presented a slight convexity backwards, instead of its old concavity. The patient who had been till then confined for the most part

of carbolic acid made by mixing one part of 1 to 20 lotion with about two parts of boiling water. When used in this way, strapping will adhere to a moist skin, so that it may be applied under the spray when circumstances render this desirable.

[1] The proportions which I have hitherto found to work best are, sixteen parts of paraffin, four parts of resin, and one part of crystallized carbolic acid. I am far from supposing that this first attempt at improving upon oakum affords the best result attainable; and I propose to institute experiments with various other constituents of tar. But it seems worth while to mention the result already arrived at, because, while it certainly works well in practice, its constituents are obtainable where lac-plaster may not be so. It has the further advantage of being a very economical dressing. For the gauze loses the paraffin and resin entirely when washed in boiling water, so that it may be used over and over again, while about a halfpenny covers the expense of the ingredients required to charge a square yard.

to bed, as a matter of precaution, was now allowed to get up, a similar dressing of 'protective' covered with antiseptic gauze having been applied.

Four days afterwards, on December 26, the dressing was again changed, when the wound over the ulna was found almost healed, and that over the joint far advanced in cicatrization, while there was still no pus or putrefactive odour, and the general health of the patient continued excellent.

In some respects it would have been more satisfactory if sufficient time had passed to permit reunion of the ulna, so that the usefulness of the limb might be tested. But as an illustration of antiseptic treatment, the case is already complete. In this respect, I cannot but hope that it will be thought instructive. It is an example of a procedure, otherwise highly dangerous, if not unwarrantable, rendered not only legitimate, but entirely free from risk, simply because, from the circumstances of the case, and the improved means at our disposal, we could calculate with certainty on avoidance of putrefaction. I venture to draw special attention to the use of the spray. In every wound treated antiseptically, two things are always to be attended to: first, to leave the wound free from living putrefactive organisms, and, second, to employ such an external dressing as shall securely prevent the entrance of such organisms at any subsequent period of the case. The latter point has, in most cases, been for a long time past satisfactorily accomplished; but the former, till we used the spray, was always a matter of more or less uncertainty. A floating germ might enter during the operation into some cellular interstice among the tissues, and, becoming surrounded with a clot of blood, might escape the action of the antiseptic lotion with which the wound was washed, and, retaining its vitality, might subsequently propagate its kind, and spread putrefactive fermentation through the wound. But by help of the spray we operate in an antiseptic atmosphere, and effectually prevent putrefactive organisms from ever entering the wound alive. We thus dispense with the necessity for washing the wound at all with an antiseptic lotion, and in the particular case above related, not even the vapour of carbolic acid penetrated into the deeper parts of the wounds, which were thus left as free from irritation as if they had been made subcutaneously.

The spray is also of the greatest value during the stitching of such wounds as require it, and rids us of the troublesome and uncertain process of distending the wound with lotion by means of a syringe, after the introduction of the last suture. In the changing of dressings, also, the spray is in some cases, and especially in stumps after amputation, a great element of security.

Revision of the proof (January 11, 1871) affords me the opportunity of giving another report of the progress of the case. On dressing the limb yester-

day, after an interval of five days, I found the ulnar wound entirely healed, while at the site of the radial incision two or three granulations about as large as pins' heads alone remained to cicatrize, and an odourless serous stain of about a minim upon the gauze was the only appearance of discharge. The ulna seemed already firmly united; and, after performing passive motion throughout the range of the natural movements of the joint, I directed him to try its powers. He could himself pronate and supinate the hand, could extend the arm completely, and readily put his fingers to his mouth; and he lifted a heavy pair of tongs, exhibiting already a strength very superior to that which he had before the operation.

THE ADDRESS IN SURGERY

DELIVERED ON AUGUST 10, 1871, TO THE THIRTY-NINTH ANNUAL MEETING OF THE BRITISH MEDICAL ASSOCIATION HELD IN PLYMOUTH

[*British Medical Journal*, 1871, vol. ii, p. 225.]

MR. PRESIDENT AND FELLOW ASSOCIATES.—My duty on the present occasion is to endeavour, if possible, to give you an address commensurate in interest with the very high honour of being selected to deliver it. With this object, instead of attempting a general review of surgery, which has been presented under various aspects by my able predecessors, I have concluded to bring before you a subject which, though in some respects a special one, is calculated, as I believe, to revolutionize almost every department of surgical practice ; I mean the antiseptic system of treatment. The fact that my name is associated with this topic tended to make me shrink from such a course ; but, on the other hand, I could not but feel that this very circumstance has led in all probability to my standing before you to-day, so that you might naturally expect to hear something from me on this subject, while it is at the same time my sincere conviction that I could not turn the present occasion to better account than by exciting in you a keener interest in the antiseptic system than it has yet elicited, and by placing you more in a position to diffuse its benefits among mankind.

Among the causes which have hitherto interfered with the general acceptance of this mode of treatment, by far the most prejudicial is the doubt of its fundamental principle, instilled by various authors who have opposed the germ theory of putrefaction, and who, supposing themselves to be advocating the cause of truth, have not only, as it appears to me, espoused the side of error, but have unconsciously inflicted an amount of material evil upon their fellow creatures such as mere speculative opinion is seldom able to produce. For few medical men in active practice have the leisure to sift and weigh the facts and arguments of such a discussion ; yet, if they lose firm faith in the guiding principle of the treatment, the attainment of a full measure of success becomes with them a matter of impossibility. 'Felix qui potuit rerum cognoscere causas' was never more applicable than here.

Another great cause of failure, and consequently of dissatisfaction with the system, is the want of practical initiation into the treatment. For, greatly as our means of carrying out the principle have improved of late, both in simplicity and in efficiency, mere description seems inadequate to convey a clear

idea of the method of employing them. Hence, while there are now scattered up and down in this country and in various other parts of the world, gentlemen who, having witnessed the treatment in our wards, whether as students or as qualified practitioners, are attaining exactly the same kind of results as we do, success seems a rare exception for any who have not had such opportunities.

I propose, therefore, in the first place to bring shortly under your notice some considerations relating to the theoretical basis of the treatment; secondly, to exhibit before you the chief means that we now employ, and, so far as this can be done upon a table, the mode of using them; and lastly, by your permission, to state some facts which I hope you may regard as sufficient evidence that, by such means employed on such a principle, we have it in our power to obtain easily and securely results of a kind that without antiseptic management the surgeon would not be justified in aiming at.

With regard to the theory of the treatment, I propose to avoid all doubtful disputations, and simply bring before you a few facts, to which I invite your earnest attention and your candid judgement.

Those of which I have first to speak have reference to the well-known experiment of Pasteur of boiling a putrescible liquid in a flask with an attenuated and contorted neck. It is now nearly four years since I introduced portions of the same specimen of urine into four glass flasks, so as to make each about one-third full, and, after washing their necks, drew them out with a spirit-lamp into tubes less than a line in diameter, and then bent three of them at various acute angles, while the fourth was left short and vertical, though equally narrow. Each flask was then boiled for five minutes, the steam issuing freely from the orifice; after which they were left with the ends of the necks still open, so that air might pass in and out freely in obedience to the condensation and expansion caused by the diurnal changes of temperature. The boiling, I need hardly say, was for the purpose of killing any organisms contained in the liquid or adhering to the sides of the glass: the bending of the necks in three of the flasks was with the view of intercepting particles of dust, which, according to the germ theory, are the cause of putrefaction, as distinguished from the atmospheric gases; while the fourth neck was left short and vertical for the sake of contrast, to afford opportunity for dust to fall into the liquid, where such portions of it as had the nature of living organisms might propagate and induce in the fluid any changes of which they were capable. The result was, that in the vessel with short and upright neck two different kinds of fungi, visible to the naked eye, soon made their appearance, and these grew steadily till they had attained large dimensions, the liquid meanwhile gradually changing from its pale straw colour to a deep amber tint, implying alteration in its chemical

constitution. But in the flasks with bent necks the fluid remains to this day entirely unaltered.[1] I regret that the distance from Edinburgh to Plymouth is too great to permit me to bring these objects before you. One perilous journey they have already had, when I took them from Glasgow to Edinburgh nearly two years ago, nursing them carefully during the railway journey, to the amusement of my fellow travellers; and in the drive from the station to my house the violent rocking of the vehicle churned up their contents till the upper part of the body of each flask was full of a frothy mixture of the putrescible liquid with the atmospheric gases; yet no harm resulted, and the fluid in the bent flasks still retains its original pellucid clearness and pale hue. Bringing these in imagination before you, as represented in this diagram, consider what these facts imply. Let us not push them one tittle beyond their inevitable interpretation. The drops of moisture deposited in the bent tubes from condensation of the steam when the lamp was removed dried up in a few days, so that the necks have been for nearly four years open and dry from end to end. Comparing the capacity of the part of the body of the flask containing air with that of the narrow neck, it is manifest that a considerable portion of fresh air has passed into the flask every night, in consequence of the fall of the temperature, a corresponding portion passing out again by day, though not the same which entered; for the diffusion of gases would ensure its mixing freely with that previously present. Hence, during nearly four years this putrescible liquid, this boiled urine, has been freely exposed to the influence of the atmospheric gases, yet it has not putrefied. About half a year after the commencement of the experiment, I decanted a little of the liquid from one of the bent flasks into a wine-glass, and found it sweet in odour and faintly acid to test-paper, while an honest search with a powerful glass failed to detect even the minutest organism. Covering the glass to prevent evaporation, I found it in two days stinking, while under the microscope it already teemed with various organisms, and a few days later it showed fungi to the naked eye. Thus the fluid was demonstrated to be still putrescible and a favourable nidus for organic development; yet both these changes have been prevented for nearly four years by the circumstance that the air, in gaining access to it, had to pass through a narrow bent tube of clean dry glass. Now such a tube could not by possibility arrest any atmospheric gas. It cannot possibly have stopped anything but the atmospheric dust. It follows, therefore, not as a matter of theory, but as an inevitable inference from fact, or, in other words, as a truth, that, so far as this particular instance of a putrescible liquid is concerned, both the

[1] Some minute shining crystals have of late been deposited on the bottom of the flasks, probably from condensation through the very slow evaporation constantly going on.

development of such organisms as the microscope enables us to detect, and the concomitant putrefactive changes, are occasioned by particles of dust suspended in the atmosphere, but not by the atmospheric gases. I confess, Mr. President, I am ready to blush for the character of our profession for scientific accuracy when I see the loose comments sometimes made upon this experiment ; and I am tempted to doubt whether some of the commentators can have enjoyed the advantages of sufficient education either in chemical physics or in logic. The simplicity and perfect conclusiveness of the experiment constitute its great charm, and render it, as it appears to me, deserving of your careful consideration. Yet, having before published an account of it, although nearly two years have since elapsed, so as to add considerably to its weight, I do not know that I should have felt justified in bringing it forward on the present occasion, if I had not an additional fact to communicate respecting it besides the results of further lapse of time. We have seen that we have been forced to the conclusion that, though the gases of the air certainly pass into the body of the flask and out again every twenty-four hours, its dust, even though of extreme minuteness, must be arrested by the contorted tube. Now, inevitable as this inference is, it will be satisfactory to have it converted into the position of an observed fact. This Professor Tyndall's simple but beautiful mode of investigation with a condensed beam of light has lately enabled me to do. Having prepared two dry glass flasks, one of them having the neck drawn out and contorted, I arranged them, through the kind assistance of my colleague, Professor Tait, so that the body of each was pierced by a beam of highly condensed sunlight in an otherwise dark apartment. The beam, scattered by the floating particles of dust, showed white in the surrounding darkness, within the flasks as well as without, proving that the air within the flasks was dusty like that outside. I now closed with sealing-wax the orifice of the unbent flask, and, leaving the other open, allowed both to remain undisturbed in the laboratory. A fortnight later I again submitted them to the solar beam, condensed as before, and now found that in both flasks alike the visible part of the beam terminated abruptly at the glass on each side, showing that in both the air was, as Tyndall expresses it, 'optically empty,' or, in other words, that it was destitute of even such minute particles of floating matter as could produce the faintest nebulosity. During the time between the two observations, the force of gravity had led to the subsidence of even the minutest floating particles ; and, though the changing temperature of the laboratory had of necessity induced the daily entrance of air into the open flask, the bent form and fine calibre of the tube by which it was admitted had effectually filtered it of suspended material, though in a very dusty apartment.

The other class of facts in this division of the subject to which I am anxious to direct your special attention was also suggested by one of Tyndall's experiments with the condensed luminous beam—that, namely, in which he proved the perfect manner in which cotton-wool filters the air of its suspended particles, by blowing against the beam with a pair of bellows having a mass of the cotton tied over the nozzle ; the result being that the beam, elsewhere white from illuminated dust, became perfectly black at the part on which the current was directed through the cotton-filter : hence the idea naturally suggested itself that cotton-wool might be used with advantage as an antiseptic dressing.[1] Of course it would be useless to apply ordinary cotton without special precautions, for, according to the germ theory, putrefactive particles must exist among the fibres and lie scattered over the wool. But if the cotton were impregnated with some volatile material capable of destroying the vitality of the septic organisms, and then placed upon the wound after washing it with a lotion containing the same substance in solution, the result ought to be, supposing the theory true, that, after the volatile antiseptic had become dissipated by diffusion from the dressing and from the wound, the cotton-wool, though destitute of any chemically antiseptic properties, should effectually prevent, by its filtering property, the access of any putrefactive agents, and keep the wound sweet, while in itself a perfectly bland and unstimulating application. Accordingly I prepared four samples of cotton-wool by diffusing through each one of the following substances—chlorine gas, sulphurous-acid gas, carbolic-acid vapour, and the vapour of benzene—four materials very dissimilar in chemical properties, but having a common hostility to low forms of life. Chlorine, sulphurous acid, and carbolic acid are well known to have such a property ; and, knowing that benzene is used by the entomologist for killing insects, and having ascertained by experiment the potency of its vapour for the destruction of pediculi, I thought it probable that it would also answer our purpose. I then dressed with these four kinds of prepared cotton-wool various suppurating sores, excoriations, and contused wounds, after washing the surface with the corresponding lotion, or, in the case of benzene, with the undiluted material. The result in every instance corresponded exactly with theory. After about twenty-four hours' exposure at the temperature of the body, the cotton-wool was found to have lost the odour of the antiseptic, yet the blood, serum, or pus, as the case might be, remained perfectly sweet for

[1] My friend Dr. Meredith, of the Indian Service, who attended Tyndall's first lecture on 'Dust and Disease', just after a visit to Edinburgh, where he had been greatly interested with the antiseptic treatment, at once wrote informing me of this experiment, and asking if I did not think that cotton-wool might be turned to account for excluding the causes of putrefaction from wounds—a suggestion which I at once proceeded to act upon as above described.

an indefinite period, while healing advanced in the satisfactory manner that might be anticipated from the absence of all irritating quality in the dressings. There was, however, one circumstance, highly instructive in itself, which interfered sadly with the utility of this application ; namely, that if the discharge happened to be sufficiently copious to soak through the cotton-wool and appear at its external surface, putrefaction occurred throughout the entire mass of the moistened part down to the wound, even within the first twenty-four hours after the dressing, if the fluid were sufficiently copious to penetrate within that period. It is only when dry that cotton-wool can arrest the progress of microscopic organisms, which have ample room to develop among its meshes when filled with a putrescible liquid.

And now, Gentlemen, allow me, at the risk of seeming tedious, to endeavour to bring home to you a little more closely the inference that is to be drawn from these facts. But, first, let me describe in detail the manner in which the dressing with carbolated cotton-wool was practised. The cotton-wool having been impregnated with about a two-hundredth part of its weight of the acid in the form of vapour, the surface of a granulating sore or abrasion was washed, together with a portion of the surrounding skin, with a solution of the acid in about forty parts of water. A piece of oiled silk of the size of the sore was then applied, to prevent the dressings from sticking through dryness. Over this was placed a piece of folded linen rag, rather larger than the oiled silk, and impregnated with the carbolic-acid vapour in the same manner as the cotton-wool ; the object of the rag being to absorb the discharge and prevent it from trickling down, as it was otherwise apt to do, below the slightly absorbent cotton, involving its early appearance at the surface and consequent spread of putrefaction to the wound. Lastly, a well-overlapping mass of the carbolized cotton-wool was securely fixed by a bandage. The result, as before stated, was that, though all chemical antiseptic virtue left the dressing within a day or two, putrefaction was excluded by the cotton-wool for any length of time, provided the discharge did not penetrate to the exterior of the mass. Consider, now, the circumstances of the serum or pus that oozed from beneath the edges of the oiled silk into the folded rag—let us suppose a week after the application of the dressing, when all traces of the volatile antiseptic had certainly disappeared. Here was a highly putrescible liquid, not subjected to boiling, as in the flask experiment, or acted on by any chemical agent whatever, yet remaining free from putrefaction in a rag moistened with it at the temperature of the human body, simply because it was covered over with pure dry cotton-wool. How, then, did this cotton-wool exclude the causes of putrefaction in the atmosphere ? It certainly did not keep out any of the atmospheric gases.

The same cause that led to the escape of the volatile antiseptic necessarily occasioned a perpetual intermingling between the external air and that between the meshes of the fabric, as any one acquainted with Graham's beautiful researches into the laws of gaseous diffusion must at once admit. The only constituent of the atmosphere which the cotton-wool could possibly exclude is its dust ; and this we know, from Tyndall's experiment, it did exclude. Here, then, we have another inevitable inference from fact, another truth, and that in itself all-sufficient, with reference to the antiseptic system of treatment ; the truth, namely, that pus, blood, and the dead tissues in contused wounds do not putrefy through the influence of the atmospheric gases, but through the operation of particles of dust, which may be permanently deprived of septic energy by the vapour of an agent like carbolic acid. I do not ask you to believe that the septic particles are organisms. That they are self-propagating, like living beings, and that their energy is extinguished by precisely the same agencies as extinguish vitality, such as heat and the various chemical substances to which I have referred, is certain, and is of the utmost practical importance. But if any one, in spite of these facts, and in spite of the strong analogy of the yeast plant, and the various kinds of fungi which we term mould, prefer to believe that the septic particles are not alive, and to regard the vibrios invariably present in putrefying pus or sloughs as mere accidental concomitants of putrefaction, or the results, not the causes, of the change, with such a one I, as a practical surgeon, do not wish to quarrel. Nor do I enter upon the question whether spontaneous generation can take place at the present day upon the surface of our globe. To do this, would be to engage in doubtful disputations, which I promised to avoid.

But I do venture earnestly to beg of all of you who are engaged in surgical practice, that you will give these simple facts your careful consideration ; and if you think the interpretation I have given a sound one, do not let any statements, whether in books or in journals, shake your belief in the truth that putrefaction, under atmospheric influence, as it occurs in surgical practice, is due to particles of dust ever present in the atmosphere that surrounds our patients, and endowed with wonderful chemical energy and power of self-propagation, yet happily readily deprived of energy by various agents which may be employed for the purpose without inflicting serious injury upon the human tissues. With this as your guiding principle, you will find yourselves successful with the antiseptic system of treatment ; but without it, whatever theory you adopt, you will ever be walking in the dark, and therefore ever liable to stumble.

And now I proceed to the second division of my subject—the exhibition

of our principal means and methods of treatment. For preventing the access of putrefactive fermentation, the agent which we now commonly use is what we have termed the antiseptic gauze, of which these are samples—being a loose cotton fabric, the fibres of which are impregnated with carbolic acid securely lodged in insoluble resin, which holds the carbolic acid with remarkable tenacity, while at the same time a little paraffin is added to prevent the adhesiveness which the mixture of carbolic acid and resin would otherwise possess. The interstices between the fibres are kept free from these ingredients, so that the fabric, being porous, may be fitted for absorbing discharges. The carbolic acid is in considerable quantity in the gauze; but it is held so tenaciously by the resin that, on the one hand, when first applied, it is unirritating to the human skin, and, on the other hand, unless discharge be very copious, it will retain its virtues for upwards of a week at the temperature of the human body. Now supposing I were going to use this gauze for dressing any case in which a copious discharge was expected—as, for example, a large psoas abscess immediately after it had been opened—I should take a considerable quantity of the gauze (about as much as one can conveniently hold between the extended hands) and fold it three times so as to make it eight layers. But there would be no use in my having the folded gauze of this extent, if I did not adopt some means for compelling the discharge to pass throughout the length and breadth of the dressing; and for this purpose some impermeable tissue must be interposed between it and the external air. That which we have found the most convenient is a cheap and light form of macintosh, termed 'hat-lining' by the india-rubber dealers. I cut a piece of this, nearly as large as the folded gauze, and then place it beneath the layer that is intended to be outward. The discharge then coming from the wound, situated opposite the middle of the gauze, instead of passing directly outwards through it, is compelled to traverse all the extent of the antiseptic dressing; and in that way, by using a sufficiently large piece, and with this arrangement of the macintosh, you may be perfectly certain that, if you leave no putrefactive mischief in a wound or abscess, none will enter it, however profuse the discharge may be during the first twenty-four hours. That is one very important point gained. As the discharge diminishes, the intervals between the dressings are extended; and when it amounts to only a minim or two in twenty-four hours, the application may be left undisturbed for a week. The gauze is also extremely convenient in the form of bandage—an antiseptic bandage—which is put on to hold the main dressing in position; and instead of being a nidus for putrefaction, as a cotton-bandage would be, it increases at every turn the antiseptic efficacy of the dressing. Besides this, the bandage having a degree of stickiness, its turns

do not tend to slip as those of a cotton-bandage do, which is an additional advantage.

Such, then, are the means by which, in ordinary cases, we ensure that putrefactive fermentation does not extend from without into the wound or abscess. Of course it would be of no use to apply such an external dressing if putrefactive particles in an active state were left within a wound. If a wound be presented for treatment, having been inflicted by another than the surgeon, some dust is sure to have been introduced ; and we must first destroy its septic energy by washing the raw surface thoroughly with some liquid trustworthy for the purpose, such as chlorine-water, or sulphurous-acid lotion, or a strong solution of carbolic acid, or of chloride of aluminium, for there are various preparations which may be used with efficiency. But when the surgeon operates on a previously unbroken integument, he has the opportunity of preventing the septic particles from entering in an active state at all, by operating in an antiseptic atmosphere. This is readily provided for in small operations by using a watery solution of carbolic acid with Richardson's apparatus for local anaesthesia. For making the spray more fine, I have found it convenient to have the lower end of the water-tube almost entirely stopped up, leaving only very minute apertures. The result is, as you see, an exceedingly satisfactory spray. For any small operation this answers the purpose perfectly well, provided always that you take the precaution of having the liquid filtered through a cambric handkerchief or some similar fabric, in order to exclude the grosser particles of dust, which otherwise would have the effect of blocking up the fine orifice at the nozzle of the apparatus—an occurrence which, under some circumstances, might be disastrous in its effect.

We have lately found that the strength of the solution employed for producing the spray may be considerably reduced. We have ascertained that it may be used as weak as one part of carbolic acid to a hundred parts of water ; and that a spray made with such a lotion is thoroughly trustworthy as an antiseptic atmosphere.

The reduction of the strength of the spray is a matter of great importance. In the first place, it is a great comfort to the surgeon, as I can testify from experience. When we used a solution as strong as one part of carbolic acid to forty parts of water, my hands were constantly in a rough and uncomfortable state ; but when the proportion is reduced to one to a hundred for the production of the spray, the hands experience no inconvenience whatever, and one can even breathe with comfort in such an atmosphere.

In the second place, it is equally advantageous for the patient, because the weaker the antiseptic application, of whatever sort it is, the less irritation

do we occasion to the tissues of the part treated with it. The antiseptic is always injurious in its own action ; a necessary evil, incurred to attain a greater good. To suppose that it is useful by its own operation in some specific manner unknown to us, is an entire mistake. I know that, not only from theory, but as a matter of experience. At one time, I used the undiluted acid ; and, in doing this, I could not avoid producing not merely irritation, but a certain amount of sloughing. Then I used a strong solution of carbolic acid in oil ; then a rather strong solution in water ; then a weaker watery lotion ; and now we employ a solution as weak as that which I have described—one part of carbolic acid in a hundred of water—and that applied only in the form of spray, avoiding absolute drenching of the tissues at all, and avoiding also the injection of the wound by a syringe, as we used to do after the operation was completed, in order to destroy the organisms introduced ; and, in direct proportion to the weakness of the solution used and to the smallness of its opportunity of acting on the tissues of the part, is the satisfactoriness of the results obtained, provided that the essential object of avoiding putrefaction is secured.

And now, supposing that I were, single-handed, about to change the dressing in the case to which I have alluded—a large psoas abscess—the spray is of extreme value. I wish that the spray shall play upon the surface of the body, in the angle between the dressing and the skin, as I lift the gauze. It would be very inconvenient if it were necessary for this purpose always to have an assistant to work the spray ; but, by a little management, the spray can be worked perfectly well, as you see, by the surgeon himself. [This is done by placing the bottle of Richardson's apparatus against the ball of the thumb, and holding the india-rubber bulb to be compressed between the opposite side of the bottle and the fingers of the same hand.] Supposing this were the site of the incision in a case of psoas abscess, as long as I choose I can perfectly protect it with the antiseptic atmosphere, and then put on what we have called, for the sake of distinction, a 'guard'—a piece of rag dipped in the one to one hundred watery solution of carbolic acid, after which the spray can be removed with security ; the surrounding parts having then been cleansed from any discharge there may be, the spray is once more made to play on the part during the exposure of the wound until the permanent antiseptic dressing is reapplied.

But, gentlemen, though such a spray-producer is perfectly efficacious for a small operation, it does not make a cloud of sufficient volume for a large one, such as an amputation of the thigh or at the hip-joint. Therefore, with the object of securing the same result in such cases, I have had this apparatus prepared, which, I confess, is in a cumbrous and heavy form ; but I hope it will be improved in that respect before long. Meanwhile, it is much better

than nothing. Let me say a word or two, in the first place, as to the principle on which it is constructed. It appears that the best kind of spray which can be produced is that which is formed on the principle of the atmospheric odorator, by having one tube set at right angles to another, the air-tube being larger than the water-tube, and the opening of the water-tube being exactly opposite the middle of the orifice of the air-tube. This makes the finest and best of all sprays. But, with a heavy apparatus like this, it would never do to have to move it about along with the nozzle, as is absolutely necessary in the instruments of ordinary construction on this principle. We must have tubes to convey the air and the water to a considerable distance ; and this is very easily done by not merely having the liquid ejected by the force of the air blown over the orifice of the water-tube, but by having it driven through the tube by the force of the same pump that propels the air, the quantity of the water being regulated by a stop-cock. Then it was necessary to provide some ready means of clearing the fine end of the water-tube, in case of its obstruction by particles of dust. This is done by having the water-tube straight for a short distance from the nozzle, and then bent at a right angle, with a little milled cap to screw on at the angle, so that, in case of obstruction, the cap is screwed off, and the orifice of the water-tube is cleared at once with a needle or a bit of fine wire. I have used this apparatus in various operations of late, among which I may mention my two last amputations, one in the thigh, the other in the arm, in both cases using nothing stronger than the one to a hundred solution for the spray, and the same for the sponges ; except only, what I believe to be a wise precaution, that, when a sponge has become soaked with blood, it should be washed first with pure water, then dipped for a moment in a strong solution (one to forty), and then squeezed out of a solution of one to a hundred to give it the necessary blandness ; and in both these cases putrefaction was entirely avoided. [The apparatus exhibited had two nozzles, attached to independent caoutchouc tubes, furnishing large clouds of spray, that could be directed, if necessary, to opposite sides of the part operated on. Two of Richardson's spray-producers, worked by two assistants, will answer the same purpose, though less efficiently.]

The antiseptic catgut ligature is used for securing the arteries while the spray still plays over the wound. It is absolutely necessary that it should be properly prepared. I must not enter into the method of preparation, further than to say that catgut undergoes a remarkable change in its physical constitution when steeped for a long time in an emulsion of water and oil, so that it becomes quite transparent, and no longer liable to become soft and slippery when placed in water or in a watery discharge. But for this circumstance, the animal ligature would be an impossibility ; but, if you use it properly pre-

pared, you will, I believe, see good reason to be satisfied with it. That which I now show is extremely fine, much finer than any silk commonly employed; and yet with a piece like this I should not hesitate to tie the femoral artery in a stump. If you choose to use it thicker for a large vessel, you can do so. It is conveniently carried on a little winder, in a capsule appended to a caustic-case. The catgut, as tied in the ordinary reef-knot with the ends cut short, seems to me to be a perfect haemostatic. It has all the simplicity and universal applicability of the ligature, with, at the same time, the virtual absence of any foreign body from the wound. If putrefaction be avoided, it is rapidly absorbed, and you may reckon as certainly on the absence of any interference with primary union on the part of such ligatures, as if there were no ligatures at all. Should putrefaction occur, I was at first uneasy lest the prepared catgut might soften and permit haemorrhage. I was, therefore, at the pains to test some of the prepared catgut in the following manner. I tied some pieces of it at intervals round a cylinder of india-rubber, so as to pinch the india-rubber to a considerable degree of constriction, and then introduced it into putrid serum of blood, and kept it for a week at a temperature of about 90°. At the end of this period the india-rubber was still constricted, showing that the catgut had retained its hold in the putrid liquid, in spite of the constant strain of the elastic material upon the knots. No doubt, in such parts of a wound as actually putrefy, the little bits of catgut must come away like shreds or sloughs of cellular tissue; but I am bound to add that this is only a matter of presumption: for, although I have used nothing but this ligature for securing vessels in wounds for more than two years, excepting torsion, which I comparatively rarely resort to, and though in certain classes of cases putrefaction cannot be avoided, in no instance have I seen the catgut knot come away, nor have I ever known secondary haemorrhage or abscess caused by its use.

I have spoken of the injury that the stimulating carbolic-acid lotion inflicts on the tissues by irritation. The great disadvantage of this is, that it causes an unusually large flow of serum during the first twenty-four hours or more, and you must provide a special exit for the serum, else you will have inconvenience from tension, which will lead to suppuration, though not of the putrefactive kind. For the purpose of guarding against this, I introduce, at the most dependent part of the wound, a strip of lint steeped in a solution of carbolic acid in about ten parts of olive oil, to serve as a 'drain'. This is drawn out under the spray in twenty-four or forty-eight hours. If you drew it out without providing an antiseptic atmosphere, you would certainly have putrefaction. In some cases, a fine drainage-tube is convenient for this purpose, if well steeped

in solution of carbolic acid. For, as india-rubber happily absorbs carbolic acid, the drainage-tube is antiseptic when introduced.

There is yet one other point to which I must allude, which is, that carbolic acid interferes with the cicatrization of a wound, if it act directly on it. This agent operates with special energy on the epidermis. Sometimes this is a convenience. For example, if we dip the forefinger into a carbolic-acid lotion, and hold it there for a second or two, we may be certain that the epidermis is so imbued with the carbolic acid, that it is for the time antiseptic, and therefore may be introduced into the cavity of an abscess or any other part which we wish to explore ; and very valuable an antiseptic forefinger often is in that way. But this action of the acid on the epidermis makes it interfere with cicatrization ; and even the gauze, though generally perfectly free from irritating influence upon the sound skin or an old scar, will frequently, if applied directly to a wound, entirely arrest new epidermic formation, and sometimes excoriate a tender young cicatrix. Something, therefore, must be interposed to protect the wound from this effect of the antiseptic. What we have generally used hitherto for this purpose is what we have called the 'oiled-silk protective', consisting of oiled silk varnished with copal varnish, which makes it much less permeable to the carbolic acid. But, unfortunately, this is not a perfect protective. It acts admirably until it becomes moistened ; but afterwards the water that penetrates the substance conveys the carbolic acid in. I have striven in various ways to get something perfect in that way ; and I have lately been engaged in a manner which, though not yet completely successful, may be mentioned on account of its interest otherwise. Some time since, I tried the effect of an oil-paint on oiled silk, in the hope that the particles of pigment, closely packed, might serve considerably to intercept the carbolic acid, though the oily material that cements the particles is permeable to it. The result was such as I had hoped, except that the material proved too stiff for convenient use. A few weeks since, however, I happened to be going through an india-rubber factory, and there I saw, among other things, the process of mixing various pigments with caoutchouc ; and it occurred to me, might not india-rubber, blended with some pigment, answer as a protective ? The india-rubber is permeable to the carbolic acid ; but with the pigment it might not be so. I first tried a coloured rubber that had been vulcanized, and then came out a most curious and interesting circumstance. The sulphur in the vulcanized india-rubber acting chemically on the discharge, the result was a stench like rotten eggs, presenting an excellent example of decomposition without putrefaction ; for there was no putrefactive fermentation—no spread of the decomposition into the interior of the wound or abscess. It was limited to the exterior,

and was simply the result of the chemical action of the nascent sulphur upon the discharges. And if, under such circumstances, we resumed the oiled silk protective, we again had perfect absence of unpleasant smell.

The necessity for avoiding any sulphur in the material was a great cause of embarrassment; for, as a general rule, the admixture of any foreign ingredient with caoutchouc causes a most inconvenient softness and adhesiveness of the product—evils which vulcanizing completely corrects. Magnesia forms an exception to this rule, producing with the pure rubber a very satisfactory substance as regards its physical properties. But then we found that, in the case of a sensitive skin, this magnesia caoutchouc produced intolerable itching and redness, for a reason which I do not quite understand. At length it occurred to me that perhaps shellac, which seems quite unirritating, might be mixed with the caoutchouc; and that this might answer the purpose. For though shellac, when once mixed with carbolic acid, holds it very tenaciously, as is seen in the lac-plaster with which some of you are familiar, yet the acid does not readily penetrate into unmixed lac. When I suggested this to the managers of the india-rubber works,[1] they told me that they had previously ascertained that shellac could be perfectly blended with caoutchouc; the product being the beautiful article you now see, sufficiently tough, yet pliant, transparent, and with no unpleasant odour, and, as I ascertained by experiment, practically impermeable to carbolic acid. Here, then, I thought I had attained the object at which I had been aiming for years; and already we were getting results of a kind we had never got before: we had reached more nearly than ever before the conditions which we know must occur subcutaneously. I had never witnessed the healing of ulcers proceed so rapidly as I have seen it under this protective, covered with overlapping gauze; but, to my extreme chagrin, I have learnt within the last few days that, in two patients with very sensitive skins, even this material produces a trifling irritation. Still I cannot but believe that we are on the verge of getting what we want in a protective—viz. a tissue perfectly bland and unstimulating in its own substance, and also quite impermeable to the antiseptic.

So much, then, gentlemen, as to our means; and now, if you will allow me a little time longer, I will tell you what I expect will be the most interesting to you all—the history of some cases illustrative of the effects of this treatment.

The simplest of all cases for antiseptic management is that of abscess; and the most beautiful, as it seems to me, in the results. It is the simplest, because here we do not apply the antiseptic to the part concerned at all; we

[1] I cannot but publicly express my thanks to the managers of the North British India-rubber Works, for the great kindness and liberality with which they have carried out these experiments for me.

only open the abscess in an antiseptic atmosphere by free incision, pressing out the pus—ensuring, in short, free exit for the contents, without the possibility of the entrance of putrefaction. The antiseptic never enters the abscess-cavity at all ; and I would beg of those who still hold the view that carbolic acid exerts its beneficial influence by acting upon the tissues of the part, to consider carefully the case of abscess—say a psoas abscess connected with diseased vertebrae. Under the carbolic-acid spray, a free incision is made into the cavity ; and I may remark that the spray is of peculiar value for this purpose, because, if an artery happen to be divided during the dissection, it can be secured without any difficulty, or it can be tied after the abscess has been opened. As we used to proceed, plunging in a knife, and effecting the opening at one stroke, if a deep vessel were divided it was a matter of very great inconvenience. Suppose now a large psoas abscess has been opened under the antiseptic spray by free incision, we press out the pus—letting out, it may be, a quart or more ; and on the following day we find, if we have emptied the abscess thoroughly, that there is not a drop of pus to be pressed out, and no pus is formed from that abscess for the future. This is a thing that must be seen to be believed. It seems so contrary to one's experience, and yet it is exactly in accordance with pathological theory. Now suppose a few more days have passed, probably nothing whatever can be squeezed from the abscess-cavity ; but, if you can squeeze out a drop of anything, it is a drop of clear serum—clear, transparent serum. Hence, Mr. President, I say it is transparently clear that the carbolic acid does not enter into the abscess-cavity at all. Still less, if possible, can it penetrate to the diseased bone of the vertebrae ; because, if the carbolic acid did enter in even a slight degree into the abscess-cavity, it would produce opacity of the serum, from coagulating its albumen. Therefore the clear drop which you press out is certain proof that the carbolic acid does not act on the affected part at all.

I have here a piece of bone which came out along with the pus from a large psoas abscess which I opened in April last—a portion of cancellated bone. I must not hand it round, because it is precious, and one similar piece has already been lost through injudicious exhibition. But you, Mr. President, can see that this is cancellated bone, proving that the abscess really did communicate with the diseased vertebrae. The patient was an adult, with an acute curvature of the dorsal region of the spine, and other symptoms of spinal disease. He had a sense of painful constriction round the waist, pain shooting down into the haunches and lower limbs ; and he was in a state of very great general prostration. Still, if we had not seen these bits of bone, it might have been said by anybody, and perhaps fairly said, ' I do not choose to believe that this

abscess was connected with diseased bone; it may have been concomitant with acute spinal symptoms, without being in connexion with the vertebrae.' But the discharge of the bone with the pus makes us sure on this point. Well, in that case the patient experienced immediate relief from his distressing symptoms, without the occurrence of the slightest febrile disturbance; and there has been no discharge of pus since the evacuation of the original contents, though up to the present time there has been still an oozing of serous fluid into the gauze, which is changed once every four or five days. Four months, you may say, is a long time for the treatment to have continued. No doubt it is so; but what is the alternative? The alternative, as we all know, either if the abscess be opened by free incision or allowed to open itself, is almost invariably death, either after an acute course of irritative fever, which we should all wish to prevent, or after a long period of protracted hectic, perhaps even more distressing. Meanwhile, the serous discharge in this case has been steadily diminishing; and I have reason to believe, from previous experience, that we shall ultimately obtain a cure.

Among other cases of this kind, I may mention one as peculiarly instructive. On the 20th of January, 1870, I opened a psoas abscess in a man twenty-seven years old, who from the age of eleven had had antero-posterior curvature in the upper dorsal region of the spine. At length a psoas abscess made its appearance, and, increasing slowly, extended far down into the thigh. I evacuated between fifty and sixty ounces of thick pus, with lumps of curdy material, and several small pieces of cancellated bone and numerous other osseous particles came out in subsequent dressings. My friend Dr. Hector Cameron (the case being a Glasgow one) undertook the after-management, continuing the antiseptic dressing, and changing it, when the serous discharge became slight, every four or five days—the lac-plaster being used; and at length, on the 5th of February last [1871] it was perfectly healed. Then, after giving the spine a few weeks' more rest (for I believe, after such an abscess has completely healed, you ought still to give the spine repose for a while, just as you would in a case of spinal disease without abscess), that patient perfectly recovered, and is now walking about, a healthy man. Here patience and perseverance, continued for more than a year, were at length rewarded by success.

In connexion with these cases of abscess, there is a curious circumstance with respect to which I must put you on your guard; that is, that sometimes the discharge, serous though it is, soaking into the gauze, comes to stink in the dressing, in the same sort of way as pus stinks when acted upon by the vulcanized india-rubber, though with a different quality in the smell. Why this is, I do not know. It seems that it is not the carbolic acid only that occasions the

chemical change, for we never had such an occurrence when we used the lac-plaster. Whether it may be the resin in the gauze, I do not know ; but certain it is that you often have some smell ; and sometimes, instead of being merely a faint odour of rotten hay or bad soap, it is exceedingly fetid. A few days before I left Edinburgh, I opened, in a little sickly, dwindled child, a conjoined psoas and lumbar abscess, associated with spinal disease. I emptied the extensive cavity by free incision in the lumbar part, and dressed with the gauze. Two or three days afterwards, on approaching the bed, I perceived a strong smell ; and, on taking off the dressings, the stench was very great. As this was the first case in which I had ever opened a psoas abscess with the one to a hundred spray, and as I had seen regurgitation of the spray take place during the operation, I confess I was alarmed at this foul smell ; but it so happened that I could squeeze out a very little fluid from the interior ; and, taking it away under the spray, and diffusing it upon a plate, so as to be able to estimate accurately any odour it might have, I found that it was perfectly free from smell. Just as in the pus under the vulcanized caoutchouc protective, there was decomposition occasioned by the chemical action of the dressing, but no putrefactive fermentation ; for that would necessarily have spread into the interior. We took the course of dispensing with the macintosh among the gauze, because my house surgeon, Mr. Bishop, has noticed that, if the macintosh be removed so as to allow free escape for the gaseous products of decomposition, you do not get nearly so much smell ; but, if the macintosh be dispensed with, you must use a greater thickness of the gauze, and dress daily. This was done ; and, within a week of the opening of the abscess, the discharge was only a few minims of serum *per diem*, and the boy had already picked up wonderfully in general health.

Ligature of arteries in their continuity presents one of the most striking illustrations of the advantages of antiseptic treatment. I have only had two opportunities, since I published on the subject, for applying the catgut in this way ; both of them were cases of popliteal aneurysm, and both were formidable from having become diffuse. One of them was in a man aged forty-seven, who had only noticed the aneurysm for five weeks, during which time it had been rapidly on the increase, so that the patient observed a change in its dimensions every day. On his admission into hospital, on the 31st of August, 1869, it reached from the upper part of the ham to the top of the lower third of the femur. At the same time it caused extreme pain, with numbness in the limb, and the knee was bent at a right angle. I tied the femoral artery at once with a stout piece of prepared catgut, cutting the ends close to the knot, and the result was that within ten days the wound was a superficial sore bridged over with cicatrix,

which afterwards healed like an ordinary narrow ulcer. There was a remarkable contrast in one particular in the treatment of this case compared with ordinary cases. Instead of leaving the patient to lie with his limb constantly in one position on a pillow until the time should have elapsed for the ligature to separate by suppuration—there being no separation to take place, and as I believed, no source of irritation present—I from the first began free movement of the limb, and at a very early period got the knee extended, to the very great advantage of the patient. I remember a precisely similar case in which I tied the vessel with silk in the ordinary way some years ago, where the patient was not able to straighten the knee for weeks after leaving the hospital ; and in fact I do not know that he is able to do so now.

The other case was much more remarkable. The patient, also aged forty-seven, but looking more like sixty-seven, presented himself at the hospital last summer with a diffuse popliteal aneurysm which had run an acute course, but already extended some way up the thigh. I urged him to come at once into the hospital. He said he had important business to attend to, and could not do so. He came back a fortnight later with the aneurysm grown to enormous dimensions laterally, and extending up to the junction of the middle and upper thirds of the thigh. At the same time, partly from haemorrhage into its own body, and partly from being worn out with the pain he endured, he was reduced to an extreme degree, so that one of the surgeons of our hospital remarked, 'He is a dying man, at any rate.' In his case, also, the knee was flexed ; there was much numbness and oedema in the foot, and no pulsation in either tibial artery. Under such circumstances, what was to be done? To open into this enormous mass by the old operation would be most unpromising. To amputate would, I felt sure, be to kill the man outright. The only alternative was to tie the artery. Considering the extent to which the huge mass had already interfered with the circulation, it seemed extremely probable that such a procedure would be followed by gangrene. Still it seemed to afford the only chance. Then the next question was, Where should it be tied ? The lower down, the further from the heart, the better, if it could be safely done. But was there any choice ? Was not the external iliac the only practicable site ? The only part remaining in the thigh was what I believe is rightly regarded as a forbidden region, from the vicinity of the profunda or other considerable branches. Yet having ascertained, by experiment, that an antiseptic catgut ligature does not weaken the artery at all, and does not make secondary haemorrhage likely to occur under such circumstances, I felt justified in putting on the ligature in this forbidden region. It is an extremely striking fact, if we think of it, that after a large arterial trunk has been tied, we never have haemorrhage on the second or third

or fourth day—never practically during the first week, we may say. The external coat, pinched in by the ligature, is always strong enough to resist the impetus of the blood, however near the ligature may be to a branch, till the tissue has undergone alteration, till it has become softened by the granulating process through the irritating influence of the septic ligature. But if the ligature be not septic, nor in any other respect irritating, there is nothing to weaken the external coat. Why should it be weakened? On the contrary, as experiment has shown in one instance, the catgut itself, becoming replaced by living tissue, acts as a strengthening ring instead of making the vessel weaker. Hence I felt justified in applying it as near as possible to the aneurysmal tumour, though this was just about the most frequent place of origin of the profunda. Catgut a good deal thicker than that which I have shown was used, the ends being of course cut short, and all went well. There was no appearance of suppuration from the vicinity of the ligature, and the enormous mass gradually became absorbed. Being much emaciated, the man put on fat so fast that we were deceived at first with respect to the diminution of the coagulated blood, which was actually going on much more rapidly than we inferred from our measurements. Ultimately all that great mass disappeared, and the patient, first hobbling with crutches, then walking with a stick, is now a hale man, using no stick at all. I should add that in the performance of the operation, though I cut down higher up than the apparent upward limit of the aneurysm, when I divided the deep fascia I found that the extravasated blood extended further than the swelling, so that I cut into the coagula of the aneurysm. What would, in all probability, have been the result of such a procedure without antiseptic treatment?

Mr. President, I have hitherto felt some hesitation in publishing cases of this kind, lest I should lead my professional brethren to do that which would only end in disaster. An eminent London surgeon wrote to me some time ago asking for catgut, as he wished to use it for tying the external iliac. I wrote back to him saying that if he did not feel sure he could avoid putrefaction in the wound, I would not advise him to use catgut, because, if the wound should putrefy, the catgut lying there, without any means of withdrawing it, would perhaps lead to unhealthy ulceration and so occasion secondary haemorrhage, as happened in a case of Sir Philip Crampton's; which was of course not treated antiseptically. But with the spray I feel that, in operations of this sort, safety is a matter of certainty. Any one of you who chooses may, I believe, tie the femoral artery with no more danger than in making a cut in the skin on the hand; and with much less danger than making a cut in the skin on the hand without antiseptic treatment in an ordinary hospital.

The catgut ligature has other applications of such interest, that I must beg you to listen to some cases in illustration of them. Those to which I wish to refer are two of irreducible hernia, which failed to yield to the treatment which Mr. Syme long advocated, that of keeping the patient lying on his back, giving a spare diet, with frequent doses of castor-oil, and daily application of the taxis. One was a ventral hernia in a young woman, originating apparently in deep-seated abscess of the abdominal wall. It was of large size, causing extreme inconvenience, and the treatment to which I have referred having failed, I laid the sac freely open so as to expose the adherent intestines and omentum which it contained, and separated the adhesions under the comparatively inconvenient antiseptic means which we then used, freely sponging with 1 to 40 watery solution of carbolic acid, and protecting such portions of the viscera as were not being immediately operated on by a cloth dipped in the lotion. When the adhesions had been all detached, by tearing or by the knife, I reduced the viscera under the antiseptic cloth as under a substitute integument, and then pared the edges of the orifice by which the sac communicated with the abdominal cavity [an oval aperture about three inches long], cutting off the peritoneum from the muscular and fibrous structures, and then stitched those edges securely with closely applied interrupted sutures of prepared catgut, the ends being cut off near the reef-knots. The external wound was then stitched and treated antiseptically like an ordinary one. During the introduction of the deep stitches the patient vomited violently, so that it was only by exerting very firm pressure that I prevented further visceral protrusion, and after going back to bed she vomited again—a tremendous test for our catgut stitches; but they stood the test. The young woman left the hospital without any hernia; and though a very small protrusion did afterwards appear below one part of the cicatrix, it was readily reducible and amenable to ordinary treatment by means of a truss.

The other case was a large umbilical hernia in a cook. It interfered with her duties very much, and at last she could hardly walk about at all. This case was treated like the last; but, in the absence of the spray, if I had known what I was about to encounter, I should not have entered upon it. It was a most laborious and protracted business, dividing very complicated intestinal adhesions by cutting and tearing, and at the same time maintaining constant vigilance in protecting the exposed intestines with the antiseptic cloths. The thing, however, was at length accomplished, and the entire mass was returned into the abdomen. The edges of the deep opening were pared and sewn together closely with catgut sutures with their ends cut short, and the external wound was closed with carbolized silk stitches, leaving an opening for a 'drain'. A large

quantity of blood happened to become effused into the sac during the first twenty-four hours, so as to reproduce the appearance of tumour, though not in sufficient amount to cause tension, and this made the absence of putrefaction and suppuration all the more striking. And now occurred a most unhappy circumstance, though at the same time instructive. The patient, who, as I afterwards learnt, had before been liable to temporary attacks of mental alienation, became, I fear, permanently mad, and a week after the operation she was up and walking about the ward, certainly testing the catgut stitches most severely, yet without any bad result. When the wound had healed, she was taken to a lunatic asylum; and I have not been able to hear of her later than six weeks afterwards, when she left for another institution of the same kind; but up to that period there had been no return of hernia. Thus, you see, the catgut stitch becomes a new engine in surgery, enabling us to attach deeply seated parts to each other, leaving the connecting medium to be removed by absorption.

As another striking illustration of antiseptic treatment, hitherto unpublished, I may mention a case of ununited fracture of the neck of the thigh-bone. The patient was a fine powerful man, forty-five years of age, who had fallen down from a cart, and broken the neck of the femur. He had been treated in hospital elsewhere; but, strange to say, according to his own statement, he was turned out of that institution in five weeks on crutches, whereas he ought surely to have had at least six weeks with the long splint; and eighteen months afterwards he applied to me. There were all the ordinary symptoms of an ununited fracture of the neck of the femur. There was shortening to the extent of an inch and an eighth, while the trochanter was correspondingly nearer to the iliac crest than on the other side, and, instead of moving in the arc of a circle on rotation of the limb, turned on its own axis with a crunching sensation. The man could not raise his leg beyond a trifling degree, or turn round, as he lay, without supporting the trochanteric region with his hand; and he could rest no weight whatever upon the limb. Under ordinary treatment, this man would have been condemned to a life of hopeless uselessness. But, considering his time of life, there could be little doubt that the fracture was extracapsular, and that, if the ends of the fragments could be brought into the condition of a recent fracture, there would be union under proper treatment, if the man survived. But to effect this would involve making a free external wound, and, for aught I could tell, opening into the capsule of the hip-joint. And would that be a justifiable procedure? Thinking the matter over, although our antiseptic means were then comparatively imperfect, I believed I could operate so as to avoid putrefaction; and I felt sure that if putrefaction did

not occur, the procedure would be free from danger. Well, if I believed that I could do it with safety, and that it would probably have the effect of restoring the man to usefulness, it became my duty to do it ; and I resolved to make the attempt. Accordingly, on the 2nd of December, 1868, the patient having been put under chloroform, I first moved the extended limb in all directions with the utmost freedom, so as to break down adhesions, which gave way with a report that could be heard all over the operating theatre. Then I applied the pulleys, and practised extension to the utmost degree that appeared justifiable, in order to draw down the lower fragments ; and, the patient being placed on the sound side, with the pulleys still in operation, I cut down above the trochanter with a free longitudinal incision, the knife being smeared with a solution of carbolic acid, in four parts of olive oil, which was also continually poured into the wound—a very inconvenient mode when compared with the spray. At length, having cut down to a sufficient depth, I found, to my joy, that the tip of my finger, dipped, of course, in the oil, could be passed between the fragments, the ends of which, though irregular, felt smooth, as if covered with cartilage. I now took a gouge dipped in the oil, and roughened the edge of each fragment, producing abundance of bone-chips. I did not think it worth while to take out the chips ; because, supposing putrefaction avoided, I expected the chips to be absorbed. A large piece of lac-plaster was then applied as an external dressing ; and, while the pulleys were still acting, a long splint was put on very firmly, with iron bars substituted for the wood opposite to the seat of operation, to permit access for dressing. A few hours later, my house surgeon came to tell me that there was serious bleeding. I went at once, and found that such was indeed the case, the blood having gone through the patient's bed, and made a pool on the floor. Without disturbing the splint, I carefully removed the dressings, and proceeded to plug the wound with long strips of lint dipped in the solution of carbolic acid in oil, feeling sure that, as there had been no material bleeding at the operation, plugging would be sufficient ; and, as I pushed these plugs home, with my fingers dipped in the oil, and felt the mass of clotted blood, with the multitude of osseous fragments among it, I almost wondered at my own hardihood in making voluntarily a compound comminuted fracture of the neck of the femur. For it is one thing to do as Mr. Cresswell, whom I see before me, did with such striking success three years ago, to treat antiseptically an existing compound comminuted fracture of the neck of the femur—and that remarkable case, resulting from gunshot-wound, ought, I think, to have attracted more attention than it did[1]—but it is quite another thing to produce such an injury voluntarily. However, the

[1] See *Lancet*, August 29, 1868.

wound was stuffed, thoroughly filled, about a dozen strips of lint, an inch broad and fifteen inches long, being employed; and the haemorrhage being thus arrested, lac-plaster was reapplied. Next day I extracted the lint, in an antiseptic atmosphere produced by the best means then at our disposal, viz. under a large cloth steeped in the strong oily solution, beneath which dressing-forceps was insinuated, and with perfectly satisfactory result. No bleeding occurred afterwards; the coagula in the wound gradually became organized; nothing more was seen of the chips of bone, except two minute, partially absorbed, spicula, which appeared at long periods; and, not to enter into needless details, that man, when last I heard of him, was walking about with a useful limb, with only three-eighths of an inch of shortening.

The freedom with which joints may be opened in an antiseptic atmosphere, followed up with antiseptic dressing, is among the most striking and valuable circumstances of this treatment. One of my earliest cases of this kind was a large loose cartilage in the knee-joint, about an inch and a half long by three-quarters of an inch broad—not a favourable subject for the ingenious and excellent method of treatment of Mr. Square of this town. I cut down freely on the loose cartilage, having carbolic acid and oil dropped on the wound. I then fixed a sharp hook in its substance; and, producing an antiseptic atmosphere, as in the last case, by covering the part with a cloth dipped in the oil, so as to prevent mischief from resulting from the regurgitation of air into the joint, hooked it out. I have since had another somewhat similar case. In both instances, I left the wound communicating with the knee-joint open, to allow free exit of the discharges; and no disturbance of the articulation took place. With the spray, the direct operation would be perfectly simple, as well as safe. As we can thus open joints without any mischief, we have the opportunity, in case of disease, of making free incisions before suppuration has occurred; and this treatment I have found to be extremely valuable in preventing suppuration and avoiding amputation or excision. Among several such cases may be mentioned one of disease of the wrist in a middle-aged woman who was admitted into the Edinburgh Infirmary in July of last year, suffering extreme pain night and day. Suppuration appearing imminent, and the case having resisted ordinary treatment, I made a free incision antiseptically down upon the carpal bones and the wrist-joint, cutting in the angle between the tendons of the indicator and extensor secundi internodii pollicis. During the following night the pain was altogether absent; and, antiseptic dressing along with perfect rest being continued, the wound soon became superficial, without any suppuration of the joint; and she left the hospital retaining her hand in perfect soundness.

Partial excision of a joint, so unsatisfactory when practised for caries with

sinuses,[1] may sometimes be performed with great advantage when suppuration has not occurred, or when the pus has been evacuated antiseptically. An instance of this occurred in my practice last spring, in a man fifty-seven years of age, with an obstinate and painful disease of the wrist affecting the whole articulation, but especially the end of the ulna, which was extremely thickened. I cut down under the spray and nipped off the end of the ulna with bone pliers, and found the cartilage rough and eroded, though without suppuration. The wound was left open at its central part, with a drain of lint soaked with an oily solution maintaining a free communication with the joint, yet healing took place without the formation of a drop of pus. The man was discharged with a strong, useful hand, but came back a few weeks afterwards, not on account of recurrence of the disease, but because he had fallen from a haystack when he was at work and broken the radius of the same arm.

Senile gangrene is, I suspect, a disease the treatment of which must undergo a complete change through the antiseptic system. Amputation in such cases is now generally prohibited on account of the great probability of sloughing of the stump. But what is the reason of this risk of sloughing ? The cause of the original gangrene is generally interference with the arterial circulation. But that interference is only sufficient to produce actual death at one spot where the disease begins, and it generally spreads by inflammation. Now dead tissues do not cause inflammation of themselves, any more than a bit of catgut does. Inflammation occurs because the dead part putrefies, and the parts in the vicinity, being weak, die from inflammatory mortification. If that be true, supposing we were to amputate and avoid putrefaction in the stump, who is to say but that sloughing, instead of being the rule, might prove the exception ? while even such sloughs as might occur, if kept from putrefying, should be limited to the extent to which the operation might interfere with the vascular supply. Having long entertained these views, I was prepared to put them in practice in the following case.

A year ago, a woman above sixty years of age came into the hospital with her little toe affected with black discoloration, which had commenced at its tip and gradually extended to its base, and she was suffering constant acute agony. After carefully washing the surrounding skin with an antiseptic lotion—for that is absolutely essential in such a case—I amputated the toe within an eighth of an inch of the black part and dressed antiseptically. The result was that the wound healed without the slightest inflammatory disturbance ; but the

[1] When an operation is performed in a part affected with sinuses, the presence of putrefaction in such tracks renders the case unsuitable, of course, for antiseptic management, as described in the text. For a special mode of dealing with such cases, the reader is referred to the article on Amputation (see p. 378 of this volume).

weakness of the tissues was indicated by the circumstance that a little bit of skin, about the twentieth of an inch in breadth, sloughed at the margin of one of the flaps, and a small piece of subcutaneous tissue also came away. Further, after a year's respite, her proclivity to the disease has been shown within the last few days by its reappearance in the tips of all the remaining toes of that foot, though the scar of the operation remains sound.

Though I regret to find that I have already greatly exceeded my allotted time, I must ask you to allow me to say a word or two regarding the treatment of ulcers under the gauze and protective. When shielded alike from the irritation of putrefaction and that of the antiseptic, ulcers heal which would otherwise refuse to do so. Last winter I had under my care in the infirmary a young man who had burnt his foot very severely four years previously by treading in molten metal, some of which ran down into his boot. The large sore that resulted had been prevented from healing completely in consequence of the shrinking of the scar, which reached from some distance up the leg along the outer part of the dorsum of the foot to the toes, of which the outermost had been so much retracted that it pointed backwards, the end of the metatarsal bone being the most prominent part. A surgeon of considerable eminence had advised amputation of the foot, and he was afterwards under my care for five months in the Glasgow Infirmary, though without any good result; and at length, not wishing to submit to amputation, he came to me for a certificate of incompetency for any active occupation. I admitted him for the purpose of trying skin-grafting; but this failed, fortunately, as it turned out, for the illustration of this branch of the subject; for, having got the putrefaction present on admission completely arrested by strong antiseptic lotions, directly applied, and afterwards using nothing stronger than one of carbolic acid to four hundred of water as a lotion, and so making the dressing as little irritating as possible, healing went on in the most steady and beautiful manner under the gauze and protective, changed once in four or five days, and the man has now a thoroughly useful foot. I do not know that any result we have obtained has given me more pleasure than this.

When I first applied antiseptic treatment to ulcers, I did not aim at better results as regards rapidity of healing than those obtained by water dressing. The object which I first had in view was merely to keep the atmosphere of our wards clear from the contamination occasioned even by healthy sores, if their discharges be allowed to putrefy. And the effects of this rigid antiseptic management upon the hospital atmosphere forms one of the most important features of the treatment. Last evening I learnt from one of the surgeons of a large Liverpool hospital the gratifying news that pyaemia has almost, if not

entirely, left wards that were very subject to it before ; and this, as far as can be ascertained by the surgeons, from no other cause than the careful carrying out of antiseptic treatment. The results of my own experience in this matter in Glasgow were published nearly two years ago ; and I may repeat now what I then said, that wards once among the most unhealthy in the kingdom were converted into models of healthiness, simply as the result of antiseptic treatment. A year ago I published equally satisfactory evidence regarding my practice in the Edinburgh Infirmary for nearly a year.[1] Another year has since elapsed, and during the whole of my Edinburgh period—now almost two years—in wards containing nearly sixty beds, we have not had a solitary case of pyaemia, whilst we are also entirely free from hospital gangrene and from erysipelas. Yet in those wards the beds are placed much closer than is in accordance with modern notions. At first I had them thinned ; but learning that patients were placed on 'shake-downs' for the night, and finding that, in spite of this arrangement, which of course was the same in effect as if all had beds, the wards remained perfectly healthy, I had the number restored to its original figure. Now I was myself at one time house surgeon in those same wards for a year and a quarter, and I need hardly say that the surgeon under whose care they used to be was a man under whom things were managed as well as they could be with the means then at a surgeon's disposal—I allude to Mr. Syme ; yet I may safely say that such complete immunity from hospital diseases never existed in those wards before the antiseptic system was introduced.

Nor has such testimony been borne by myself alone. Professor Saxtorph, of Copenhagen, in a letter which I communicated to the *Lancet* a year since,[2] published most striking information as to a very large hospital previously extremely liable to pyaemia, so that the smallest wounds often gave rise to it, yet remaining for a year absolutely free from the disease, and, so far as he could judge, from no other circumstance than the rigorous adoption of the antiseptic system. Equally satisfactory evidence regarding the healthiness of hospital wards brought about by this means has been given in one of the Blue Books of the Navy by Dr. Bernard, of the Naval Hospital here.

After statements of this conclusive character have been published regarding what is generally admitted to be the most urgent medical question of the day, when I consider the apathy with which they have been received in many quarters, I cannot avoid being reminded of the language of Macbeth—

> Can such things be,
> And overcome us like a summer's cloud
> Without our special wonder ?

[1] See pp. 123, 159 of this volume.

[2] See p. 156 of this volume.

Mr. President, before I sit down, I must make an apology for the large share which my own performances have had in this address. For this defect I crave your kind indulgence, and only beg you to believe that I am actuated by other than selfish motives. For sure I am that, however much the means of carrying out the antiseptic principle may come to vary from those which we now use, the principle itself will certainly be ultimately recognized as the most important of all those that shall guide the practice of surgery ; and the sooner our profession is aware of this, the better will it be for suffering humanity.

ON ANTISEPTIC DRESSING UNDER SOME CIRCUMSTANCES OF DIFFICULTY, INCLUDING AMPUTATION AT THE HIP-JOINT

[*Edinburgh Medical Journal*, vol. xvii, 1871–2, p. 144.]

AT a meeting of the Medico-Chirurgical Society of Edinburgh on the 6th of June, a communication was made by Mr. Lister to the following effect :—

Mr. President.—I have to exhibit this evening, in the first place, a case illustrating *the results of excision of the wrist for caries*, performed according to the principle and method described by myself in the *Lancet* several years ago[1]; the principle being the removal of the entire articular apparatus of the wrist, including all the carpal bones, together with the articular extremities of the radius and ulna and five metacarpals, so as to place this excision in the same favourable position as that of the elbow, while the method (fully described in the *Lancet*) permits free access to the affected bones with the least possible injury to the tendons. The young man now before you is Case 5 of those described in the *Lancet* (March 25, 1865), and I may quote shortly from the account there given.[2] 'Thomas Morris, aged twenty-one, a miner, was admitted on the 8th of July, 1864. About six months before, when suffering from small-pox, he was seized with inflammation in the right tibia and the left carpus, resulting in necrosis of the former, and caries of the latter. When he came into the hospital, the back of the wrist was swollen, and presented two sinuses, through which a probe could be passed down to the diseased bone. The hand was extremely feeble, and drooped when the arm was extended horizontally. It was very painful, interfering seriously with his night's rest, and his general health was otherwise much deranged, his pulse being 135, and his appetite impaired, while he was constantly bathed in perspiration.' On the 16th of July, I removed the parts represented in a sketch given in the *Lancet*, as you will see from the copy I have brought with me. (The sketch is reproduced on p. 200.)

You observe, it includes the entire articular apparatus of the wrist. 'A carious cavity occupied the place of the semilunar bone, and the adjacent part of the cuneiform was excavated. The other carpal bones, except the trapezium, were anchylosed into one mass.' Nearly seven years having elapsed since the operation, we are in a good position for judging of its results. You observe that the hand has, on the whole, a very natural appearance, but that

[1] See p. 417 of this volume. [2] See p. 423 of this volume.

it presents at the dorsal aspect a transverse prominence, caused by the growth of new bone from the divided end of the radius, which seems to have become expanded into a socket for the reception of the ends of the metacarpal bones which have been rounded off by ossific deposit. Thus, a new joint has been constructed, of a form which, I may remark, I have seen in another case after the same operation. The formation of new bone has not taken place to the same extent from the ulna, and the hand has in an exaggerated degree the droop to the ulnar side which it assumes in the normal condition of the limb in a state of repose. Nevertheless, eversion and inversion of the hand can be carried through as great an angle as usual, proving that the tendons of the flexors and extensors of the wrist, necessarily divided in the operation, have formed secure new attachments. Flexion and extension of the wrist, and pronation and supination, are, you see, freely performed, and every joint of every digit has its normal movement, those of the knuckles only being not quite so free as in the other hand. You remark the perfect freedom of the actions of the second joint of the thumb, the extensor secundi internodii pollicis having been left intact by placing the radial incision in the angle between it and the indicator, where the cicatrix is still seen. The hand has a powerful grasp, as any of you may be satisfied by shaking hands with him. [The patient, before thus exhibiting his powers to the members of the Society, made a statement to the effect that he was engaged in charge of a steam-engine, and found his left hand equal to the right for all sorts of work, including wheeling a heavy barrow, and various other actions of a laborious and complicated character.] This case, Mr. President, is certainly very gratifying, as an example of what may be done in the way of saving a hand from amputation by means of excision ; but it is still more gratifying to be able to avoid excision by early free incision, practised antiseptically, before sinuses have formed, and followed up by antiseptic dressing. Five cases of this kind in the adult have occurred in my practice in the course of the last year, and useful as is the hand which you have just seen, it is of course not equal to the perfectly natural condition that may be retained by antiseptic management.

The next case I have to show illustrates what I believe will be found a valuable method of treatment for certain cases of

Deformity from Contracted Cicatrix.—This young woman fell into the fire

when an infant, burning the left side of the body to a frightful extent, the scar being seen to reach from the upper part of the neck to the lower part of the forearm, and laterally from near the spine to the mamma, the mammilla having been destroyed. The healing of the huge granulating sore, and the subsequent shrinking of the cicatricial tissue, led to the formation of a web of several inches in length, constituting an extension of the posterior fold of the axilla downwards, and binding the arm pretty closely to the side. We all know how unsatisfactory the treatment of such cases commonly is. The web, if divided with the knife, becomes reproduced by the coalescence and contraction of the granulations, and the condition of the patient is too often little, if at all, better than it was originally. In the present instance the tendency to coalescence of the granulations has been counteracted by a method which I employed first several years ago in a case of webbed fingers, viz. bringing the elastic traction of india-rubber to bear upon the angle of the wound made by cutting through the web. At the same time this plan of treatment has been greatly assisted, both in the earlier and later stages of the case, by antiseptic management. The irritation of the cut surface by putrefaction being avoided during the first few days after the operation, inflammation was entirely prevented, and thus we were able, even from the first, to use a degree of freedom with the limb in raising it from the side, which would have been otherwise intolerable. It happens that I have now under my care in the infirmary another similar case, operated on only two days ago, when a web of great length, and involving the whole breadth of the axilla, was freely divided; and my friend Dr. Holmer, of Copenhagen, who is here to-night, and who saw the patient dressed this morning, can bear me out when I say that the skin around the very extensive raw surface was perfectly free from redness or tenderness; while the young man was able to get up and move about almost as if nothing had been done to him. The advantages of antiseptic treatment have been equally great in the further progress of the case before you, for when sores are efficiently protected both from the irritation of putrefaction and from that of the antiseptic, they heal under circumstances inconsistent with cicatrization under water dressing; and the mechanical irritation involved in the varied traction to which the sore has been here exposed, would probably have prevented healing altogether had the ordinary application been made. I have thought it best to exhibit the patient before healing is complete, in order that you may see the treatment in progress; and as the mode of dressing presents several features of interest, I will venture to trespass upon your time by performing it before you. The retaining bandage being now removed, you see the rod of india-rubber [a rod of vulcanized india-rubber about as thick as the little finger] which exerts its

traction upon the angle of the wound in the axilla. Its ends are attached to pieces of bandage which are tied in a half-knot over the top of the shoulder and then secured to the ends of a padded handkerchief passing under the other armpit, the shoulder being protected from the pressure of the knots by a shield of thick gutta-percha moulded to it. It is three days since the dressing was last changed; yet it remains perfectly free from putrefactive smell, implying that the antiseptic gauze, which is the essential material of the dressing,[1] has answered its purpose well; and the axilla is a situation that illustrates the perfect manner in which it adapts itself to any irregularities of surface. Between the gauze and the healing sore is interposed the oiled-silk 'protective', to exclude the irritating influence of the antiseptic; and, in this particular case, the value of the protective is especially marked. For, if it were omitted, not only would the progress of cicatrization be arrested, but, as we have found by experience, the newly formed cicatrix being weak from the traction to which it is subjected by the old scar around, becomes excoriated under the influence of the carbolic acid furnished by the gauze. Under the protective, on the other hand, healing proceeds securely and uninterruptedly.

In the earlier stages of the case the protective rendered further service, because, being applied next to the raw surface, it prevented the possibility of the granulations coalescing below the caoutchouc band, and enclosing it in a tube of granulation structure.

You observe how efficacious the india-rubber band has proved. According to the tightness with which it is tied up, the pressure which it exerts upon the angle of the wound can be precisely regulated, so as to cause continuous ulceration, if desirable; and thus, so far from the angle of the wound becoming filled up by granulations, the original incision has been, as it were, extended by the ulcerating process considerably beyond its original limits, yet without any pain to the patient; and you can observe the fibres of the pectoralis major and latissimus dorsi lying bare in the groove which the caoutchouc rod occupied. Meanwhile cicatrization has advanced both on the chest and on the arm almost up to the margins of the groove. The india-rubber rod, as soon as it is removed, is well washed with watery solution of carbolic acid; and, as caoutchouc imbibes the acid, it becomes itself antiseptic for the time being. The sore having been also washed with the lotion [a solution of one part of the acid in two hundred parts of water is sufficiently strong for the purpose], I now apply a piece of protective dipped in the same liquid, and outside this the rod of india-rubber,

[1] This gauze contains carbolic acid stored in insoluble resin among the fibres, with the addition of paraffin to avoid undue adhesiveness, in the proportions of one part of carbolic acid, five parts of resin, and seven parts of paraffin.

and then a piece of well-overlapping antiseptic gauze, bandaged securely both to the arm and to the chest.

The gutta-percha shield for the top of the shoulder is padded with the gauze; and this illustrates another valuable use of that material. Supposing that the padding were of an ordinary kind, such as cotton-wool, putrefaction could hardly fail to take place in the sore. For the edge of the protective comes up to the immediate vicinity of the shield, and the discharge escaping from beneath it would soak into the padding and putrefy there, and the fermentation would be communicated to the fluid beneath the protective; since this layer, while it protects the sore from the irritation of the antiseptic, necessarily involves liability of any organic material that lies beneath it to putrefaction on access of the ferment. But by having the padding of the shield itself antiseptic this difficulty is overcome, the gauze of the axilla and that of the shield coming in contact with each other; and we have not had putrefaction occur on any single occasion since the operation. The advantages of this material are still further exemplified in this case by its use in the form of bandage, every turn of which, instead of affording a nidus for putrefaction, increases the antiseptic efficacy of the whole dressing.

It yet remains to show you what the patient can do in the way of raising the arm. At the time of the operation I did not get it quite up to the horizontal level. In the course of a few days it could be brought up to that level. Then her ambition came to be to reach up with her finger-tips to the handle of a small cupboard in the ward, fixed at some distance above the floor. Afterwards, stretching a little higher day by day, she was at length able to reach to the top of the cupboard, about nine inches higher; and now, within the last few days, by means of this species of gymnastic exercise, she has succeeded in getting her knuckles even higher than the top; and you see at present that she can raise both hands well above the head, and touch nearly as high a point on the wall with the one as with the other. Thus, instead of the usual course after such operations—namely, the web gradually forming again, and what was gained at the operation being ultimately lost—we have here made constant progress in advance of what the operation effected, and all this without the use of any means of extension, or any restraint upon the natural actions and usefulness of the limb. There can therefore, I conceive, be no doubt that, by persevering a little longer with the same system, we shall attain all that can be desired.

The next case I have to bring before you is an instance of recovery after *primary amputation at the hip-joint,* a thing by no means of common occurrence. The injury that necessitated the operation in the boy now before you (five

years of age) was of extreme gravity. The little fellow had been endeavouring to climb up into a luggage-truck, when his right leg became entangled in one of the wheels, and frightfully mangled. The hamstrings and popliteal vessels were torn through, the knee-joint opened posteriorly, the femur fractured in the wound, and the soft parts of the thigh contused to so high a level, that I was obliged, as you observe, to make the anterior flap shorter than usual, and eke it out by extending the posterior flap ; and, in spite of this, a small portion of the anterior flap lost its vitality from being implicated in the contusion. Now, there can be no doubt that, under such circumstances, the avoidance of putrefaction in the large wound was a most important condition of his recovery. Considering the state he was in, I believe that, if we had not succeeded in this respect, he would not have been alive before us this evening ; and my reason for bringing him here is, that he affords another striking illustration of the advantages of our present mode of antiseptic dressing.

Of all incised wounds, those resulting from amputation have been the most difficult to manage antiseptically ; and of all stumps, that at the hip-joint is the worst to deal with. When a stump has considerable length, we have for some time past managed quite satisfactorily by having it enveloped in about eight layers of the gauze, a piece of impermeable tissue, such as thin macintosh cloth,[1] being placed beneath the outer layer to compel the discharge to travel throughout the extent of the antiseptic tube formed by the dressing, before reaching the external air. The essential condition of free overlapping of the surrounding skin is thus complied with, while the use of a spray of carbolic acid lotion avoids any chance of the entrance of septic mischief during the changing of the dressing. But in a case like this, such an arrangement is of course impossible ; and we had two special difficulties to contend with. One was the vicinity of the inner angle of the wound to sources of putrefaction in the perineum. This was overcome partly by stitching up the wound very closely at the inner side, and having the ‘ drain ’ (of lint soaked with carbolized oil) projecting towards the outer aspect, so that discharge might be as small as possible towards the perineum. At the same time, the gauze, from its absorbent as well as antiseptic property, was of the utmost value, and, being folded of double thickness at the perineal side, answered the purpose completely ; while in this case, as in the last you saw, the antiseptic quality of the bandage was of peculiar value, every turn round the perineum adding to the antiseptic security. And I may notice here another incidental advantage of this bandage, namely, that the slight adhesiveness which it possesses makes it cling to the part to which it is applied, and prevents the turns from slipping, as those of

[1] This tissue is known by the caoutchouc manufacturers under the name of ‘ hat-lining ’.

a calico bandage are so apt to do. I should add that, during the changing of the dressings, two of Richardson's spray-producers, worked simultaneously by two dressers so that each commanded half of the large wound, proved adequate to the purpose.

The other great difficulty was the vicinity of the wound to the bed. Had the discharges been permitted to soak into the bedding, they would have soon putrefied there after losing the volatile antiseptic ; and the products of putrefaction, soaking back into the dressing, would in all probability have neutralized its antiseptic virtue, and the fermentation would have penetrated to the wound. This danger was averted in the simple way you see here illustrated—by having the gluteal region repose on a layer of folded gauze lying on a piece of macintosh cloth. In this manner the bed in which he lay was rendered itself antiseptic at the part with which the wound was concerned, and putrefaction was avoided from first to last.

While speaking of the advantages of the gauze, there is one other to which I cannot forbear alluding. If you apply this mass of it, consisting of thirty-two layers, closely to the face, you find you can breathe freely through it, as through a respirator. Hence, Sir, one great advantage of this dressing will be, that it will deprive those who discuss the antiseptic treatment of all excuse for speaking of it as operating by ' excluding the air '. We do not exclude the gases of the atmosphere at all, but adopt efficient means to destroy the energy of its floating ferments.

ON RECENT IMPROVEMENTS IN THE DETAILS OF ANTISEPTIC SURGERY

[*Lancet*, 1875, vol. i, pp. 365, 401, 434, 468, 603, 717, 787.]

SINCE the delivery of my address at the Plymouth meeting of the British Medical Association in 1871,[1] various improvements have suggested themselves in the means of carrying out the antiseptic principle. Some of these improvements have been the results of more extended experience with the materials previously in use, while others have consisted in the employment of new antiseptic substances.

With regard to materials previously in use, I wish in the first place to correct what I fear was a mistake made in the Address as to the strength of the watery solution of carbolic acid to be used for the sponges during operations, and for the cloths employed for washing and guarding wounds in changing dressings. Anxious to reduce the strength of the solution as much as possible, in order to avoid needless irritation of the tissues by the acid and at the same time to promote the comfort of the operator, I had thought myself justified by experience in recommending a lotion as weak as 1 to 100. I have since had reason to believe that in so doing I had gone beyond the limits of safety ; so that I have returned to the 1 to 40 lotion for the purposes referred to, while the saturated watery solution (1 to 20) is still employed for purifying the epidermis of a part about to be operated on, for cleansing dirty instruments and sponges, and also for washing accidental wounds, so as to destroy once for all any septic organisms that may have been introduced into them.[2]

A solution of carbolic acid of the strength of 1 to 40 is that which I would advise for providing an antiseptic atmosphere in the form of spray when the particles of the liquid are dispersed by means of air impelled by hand-bellows or a condensing pump. But I have of late found it more convenient to use high-pressure steam as the motive power, on the principle of Siegle's steam inhaler,

[1] See p. 172 of this volume.

[2] For cases of compound fracture seen for the first time several hours after the accident, I have of late used a still stronger antiseptic in the form of one part of carbolic acid dissolved in five parts of spirit of wine, introduced into the recesses of the wound by means of a gum-elastic catheter connected with a syringe by a piece of caoutchouc tube. In this way the antiseptic is made to penetrate the coagula in the various parts of the wound more effectually than it could be by forcing it in through the external orifice, while at the same time we avoid the needless disturbance which this procedure may entail in consequence of the irritating liquid being driven for a greater or less distance through the cellular interstices of uninjured parts.

the apparatus, modified to adapt it for our purpose, being both self-acting and self-directing, so as to dispense with the services of an assistant. But in this case the water of the condensed steam dilutes the solution with which it becomes blended in forming the spray, so that it is needful to use a larger proportion of the acid. In the machines hitherto constructed, one part of water is consumed by ebullition for three parts of solution sucked up to mingle with it, and thus 1 to 30 is the proper proportion of the acid in order to form a 1 to 40 spray.[1]

As a dressing for excluding putrefactive fermentation from wounds, the antiseptic gauze, which contains in its fibres carbolic acid stored up in common resin, which is of course insoluble in the discharges and holds the acid with great tenacity, has continued to prove thoroughly trustworthy if properly used; so that, provided always we have the essential condition of a sufficient space of skin in every direction from the wound for the gauze to cover, we may be quite sure that a wound left free from the causes of putrefaction when dressed will be found similarly aseptic when we change the dressing—a fact which no one, perhaps, who has not gone through the labours and anxieties which have fallen to my lot in striving after its attainment can fully appreciate. Under ordinary circumstances we still use the gauze in eight layers, with a sheet of some trustworthy impermeable tissue placed beneath the outermost layer to prevent the discharge from soaking directly through the dressing, for if it did so a copious effusion might wash out the antiseptic from the part immediately over the wound and putrefy within twenty-four hours. The most durable and therefore most reliable material for the purpose, consistent with the requisite lightness, is a fine cotton cloth with a thin layer of caoutchouc on one side, known in the shops as hat-lining or thinnest macintosh. This, if of good quality, may be used for the same case for weeks together. But, unless particular care is taken with its manufacture, the caoutchouc layer tends to adhere in the folds which it acquires from the various altered positions of the dressing, and portions of it may then be torn off when the folds are straightened out, thus destroying the essential property of impermeability; and if the macintosh be still used in that condition, entire failure of the dressing may result.

I have just now under my care a case in which I opened antiseptically an abscess connected with disease of the hip-joint, where all went on typically for a considerable time, the discharge being merely serous, and so diminished

[1] Different steam spray-producers may differ in this respect in consequence of slight variations in the relative sizes of the orifices for emitting the steam and lotion respectively. It is therefore right that in every case the actual proportion between the steam and solution consumed should be ascertained by the maker, and stated to the surgeon. In absence of such information the surgeon can readily settle the point for himself by working the spray for a while with given quantities of water in the boiler and lotion in the bottle, and then measuring the amount remaining in each vessel.

in quantity that the dressing was left unchanged for several days together, when, in consequence of imperfection of the macintosh, the discharge was observed to have soaked directly through the dressing opposite the wound, and, apparently as a result of this, putrefaction had crept in, which soon led to profuse suppuration and hectic, necessitating excision of the hip-joint.

It is therefore needful to have this material specially prepared to obviate the tendency to adhesiveness. And in all cases a second piece of the macintosh should be at hand, so that when one piece is observed to become impaired by wearing, the other may be substituted for it.

The macintosh having no antiseptic property except mechanically by its impermeability, but, on the contrary, being, like other indifferent materials, covered more or less with septic matter, it is necessary, when the dressing is a compound one, or, in other words, consists of more pieces than one, that the macintosh be well covered in at the place of junction of the two pieces, for if it were allowed to project uncovered in the vicinity of the wound, it might communicate septic mischief.

As an example of a compound dressing may be given one which, from the frequency of the cases requiring it, is the most important of all—viz. that used after removing the mamma. It consists of two pieces of folded gauze and macintosh, a posterior and an anterior one. The posterior portion is about half a yard square, and reaches vertically from above the acromion to a little below the elbow, and transversely from the spine to the arm, which it envelops as it lies beside the chest, thus forming a complete antiseptic basis for the region of the shoulder, and effectually guarding against what would otherwise be most difficult to avoid, the extension of putrefaction from the bedding through the axilla into the outer angle of the wound. The anterior dressing, though not so broad as the posterior one, is of about equal length, so that when applied to the chest it may reach from some inches beyond the anterior angle of the wound to the posterior dressing, which it joins below the back of the axilla ; and here it is that it is needful to have the macintosh well covered in among the folds of the gauze. The infra-axillary region being the part where the chief discharge occurs, it is of the utmost importance that the outer part of the anterior dressing be maintained well in apposition with the skin, and this is ensured by stuffing a substantial mass of gauze irregularly packed together between the patient's side covered by the dressing and the lower part of the arm. This additional mass of gauze has the further advantages that it serves as a supplementary antiseptic material to absorb the discharge, and that it prevents the arm from being closely pressed to the side—a position which, besides being irksome to the patient, would entail the serious evil of interference with free drainage from

the outer angle of the wound. In order to prevent the occurrence of bed-sore over the external condyle, a wisp of gauze, twisted and rolled together in the form of a ring, is placed beneath the elbow so as to receive the bony prominence in its hollow. The whole dressing is secured in position by suitable turns of a gauze bandage, which is extremely convenient on account of its lightness, and also from the circumstance that the slight adhesiveness of the material with which it is charged checks the tendency of one turn to slip upon another, so that it is more secure than a common cotton roller, besides the advantage that it increases the antiseptic efficacy of the dressing. But, on account of its loose texture, it cannot be properly fixed by ordinary pins, which would be liable to shift their position in it. Those called safety-pins, made on the principle of a brooch, should therefore always be employed; for there are cases in which the slipping of a single pin might, by allowing the dressing to shift its place, endanger the life of a patient.

There is another point in the use of the gauze to which I wish to direct special attention. The very quality which makes this material so valuable as a permanent antiseptic dressing, and renders it both mild and persistent in its effects—namely, the tenacity with which the resin in its fibres holds the carbolic acid—may become a source of serious danger at the time of application. For at ordinary temperatures of the air the antiseptic is given off by the gauze in such extremely small amount that particles of dust falling upon it cannot be expected to be deprived of septic energy by contact with it, as they are by a 1 to 40 watery solution. Hence, if a piece of gauze is applied dry to a wound communicating with a cavity containing blood, serum, or pus, as in a compound fracture, a stump after amputation, or an abscess, portions of septic material on the surface of the gauze may become mingled with the discharge at the outlet, and, thus shielded from the subsequent action of the carbolic acid, may spread fermentation into the interior. Had it not been for the use of the spray, which plays on the under surface of the gauze when applied, I cannot doubt that this cause would often have led to failure. But considering the very short time during which the spray often acts on the gauze, it is plain that it would be imprudent to trust to it for purifying the surface. This, however, can be done with the utmost readiness, either by wetting with the 1 to 40 lotion the part of the gauze dressing which is to go next to the wound, or, what is commonly more convenient, by applying to the wound itself a separate piece of gauze soaked in the lotion, and over this the dry gauze in its eight layers. When the discharge is slight, a single layer of this moist loose gauze is sufficient, but if it is copious the wetter portion must be substantial.

In situations where there is not as much extent of skin for the gauze to

overlap as is desirable—for example, in the vicinity of the pubes, as after herniotomy—the deficiency of surface of the dressing may be compensated by using the gauze in a thicker mass ; say in sixteen or thirty-two layers. By this means such wounds may be securely kept from putrefaction, which with only eight layers it might be impossible to avoid.

Details like these, tedious as they are to describe, are of course very easy of execution, and attention to them will, I doubt not, be rewarded, in the hands of others as it has been in my own, by a constancy of results which leaves little if anything to be desired.

With regard to the times of changing the dressing, it is, as a general rule, prudent to inspect the wound the day after its infliction, whether it be accidental or the result of operation. But during the subsequent progress of the case the gauze may be left undisturbed for periods varying from two days to a week, in proportion to the diminution of effusion ; the general rule being that the dressing should be changed on any day on which the discharge is observed to have extended beyond the edge of the folded gauze so as to make a stain upon the clothes or bedding.

Invaluable as the gauze is, I greatly regret to find that its use is restricted by the high price at which it is often sold. I will, therefore, now describe the manner in which it has been prepared for a long time past at the Royal Infirmary of Edinburgh, with the effect of reducing by more than half the wholesale price previously paid by the institution. First I may remark that the chief element in the cost is the cotton cloth, the expense of the materials with which it is charged being less than a farthing per square yard of the gauze. It is therefore of great importance to obtain the muslin as cheap as possible from the manufacturer, and a little saving is effected by having it unbleached. The materials used for charging the gauze are—1 part of crystallized carbolic acid, 5 parts of common resin, and 7 parts of solid paraffin ; the last ingredient being used for the purpose of preventing undue adhesiveness. Paraffin has this advantage compared with any other substance of similar consistence with which I am acquainted, that it does not blend at all with carbolic acid in the cold, and therefore simply dilutes the mixture of acid and resin, without interfering in the least with the tenacity with which the resin holds the acid. If, for example, we compare it with a substance like spermaceti, we find that a mixture of 1 part of the acid with 5 parts of resin and 5 parts of spermaceti is really much more pungent to the tongue than the 5 parts of resin and 1 of acid alone. For although the former mixture contains only half the quantity of the acid, yet the spermaceti, blending with the acid like the resin but holding it less firmly, takes the acid from the mixture and gives it up to surrounding objects. Such

a mixture of resin, spermaceti, and carbolic acid, therefore, though admirable in consistence, would be both less mild and less permanent in action than the resin and acid alone. The addition of paraffin, on the other hand, has no other effect on the mixture than to render it somewhat more mild. It seems needful to point out this circumstance, because, from want of knowledge of it, modifications of the gauze have been suggested in which the paraffin has been replaced by other materials, which cannot fail to be disadvantageous.

In order to charge the gauze, the paraffin and resin are first melted together in a water bath, after which the acid is added and blended by stirring. The object now is to diffuse this melted mixture equably through the cotton cloth, and for this purpose two things are requisite—viz. that the cotton be at a higher temperature than the melting-point of the mixture, and that it be subjected to moderate pressure after receiving it. The cotton cloth, a yard wide, is cut into six-yard lengths, and these, having been folded so as to be half a yard square, are placed in a dry hot chamber formed of two tin boxes placed one within the other, with an interval to receive water, which is kept boiling by fire or gas beneath, the upper edges of the boxes being connected and provided with an exit-pipe for the steam. There is also a glass tube arranged as a gauge of the amount of the water, and the chamber has a properly fitting lid. The bottom of the chamber is strengthened with an iron plate, to enable it to bear the weight used for compressing the gauze when charged. This is a piece of wood, about two inches thick, nearly fitting the chamber, covered with sheet-lead, so as to make it about as heavy as a man can lift by means of two handles in the upper surface. The weight is heated along with the cotton, and is put first into the chamber so as to leave the cotton loose for the penetration of the heat, which occupies two or three hours. The cotton, when heated, is taken out of the chamber along with the weight, and placed in a wooden box, to protect it from the cold. (It would be better to have a second hot chamber for this purpose, since in cold weather the cotton is apt to be too much cooled in spite of the protection of the wooden box.) The heated gauze is then at once charged with the melted mixture of carbolic acid, resin, and paraffin, in quantity equal to the weight of the cotton fabric (or slightly less), and, in order to diffuse the liquid as equably as possible, it is sprinkled over the gauze by means of a syringe with a number of minute perforations in its extremity, the body of the syringe and the piston-rod having each a wooden handle to protect the hands of the workman from the heat. The syringe is constructed to hold half the quantity of the mixture required for charging one piece of cloth. One folded piece being placed at the bottom of the hot chamber, its upper half is raised and turned aside, and one syringeful is sprinkled over the lower half. The upper

half is then put back into position and another syringeful thrown on. The same process is repeated with all the other pieces of gauze, after which the weight is put into the chamber to compress the charged cotton, and the lid applied. An hour or two are then allowed to elapse to permit the complete diffusion of the liquid, when the material is fit for use.

The apparatus above described can be constructed by a common tinman for about £10; and it is estimated that the entire cost of the gauze to the Edinburgh Infirmary, including the price of materials and manufacture, is somewhat less than 2*d.* per square yard. For hospital purposes this expense is further reduced by the fact that the gauze, after being used for dressing a case, can be entirely cleansed of the substances with which it was charged by washing in boiling water, care being taken to press it well in the hot water with a suitable wooden implement. The cotton cloth is then even better adapted for the purpose than it originally was, having lost the slight rigidity caused by the starch or gum used to stiffen the threads before weaving. Thus the same piece of cotton may be used over and over again, with saving to the institution of the chief cost of the material, which, as before said, is that of the cotton. Practically, however, it is only larger dressings which will repay the trouble of washing and arranging in proper masses for recharging.

Solution of carbolic acid in the fixed oils, which, as regards the tenacity with which they hold the acid, occupy an intermediate place between the watery solutions and the resinous mixture in the gauze, has been for the most part superseded by these latter; a watery solution being more efficient as well as more cleanly for a detergent lotion, while the resinous mixture is more mild and more persistent, and therefore better adapted for a permanent dressing. There are, however, some circumstances in which the oily solutions are valuable. For lubricating instruments introduced into the bladder, such as catheters, bougies, sounds, or lithotrites, I have for some time past used a solution of one part of carbolic acid in twenty parts of olive oil[1]—a proportion which, while unirritating to the urethra, is trustworthy as an antiseptic; and there can be no doubt that the avoidance of putrefactive fermentation within the bladder is in many cases a matter of vital importance. In using a catheter, the interior of which cannot be kept clean, but must have more or less of foreign material encrusted upon it, some of which might by chance enter the bladder from regurgitation, the instrument should either be kept for several minutes with the carbolic oil within it before it is passed, or, what is more efficient and saves

[1] The practice of using carbolized oil for lubricating instruments introduced into the bladder was first suggested, so far as I am aware, by Professor Rolleston, in his address on Physiology delivered at the Oxford meeting of the British Medical Association. (See *British Medical Journal*, August 15, 1868.)

time, it may be washed out with the 1 to 20 watery solution before being smeared with the oil. Washing urethral instruments with such a lotion will probably have the further important advantage of securing us against the conveyance of specific virus from one patient to another by their means. For a protracted experimental investigation into the subject of putrefaction and other fermentative changes having proved to me the perfect efficiency of the 1 to 20 watery solution of carbolic acid in destroying minute organisms of a fungoid or bacteric nature, I feel that we can hardly be wrong in assuming its destructive effect upon the viruses alluded to, which, though not proved to be organisms, analogy leads us to regard as in all probability of such a nature. If this be so, the use of such a lotion and lubricating oil for specula and other articles used in female complaints will prevent in the other sex the lamentable results which have now and then occurred from instrumental infection.

Cases from time to time arise in which it is desirable to have an antiseptic in constant active operation on the interior of a wound, necessitating the frequent renewal of the dressing ; and for this purpose a solution of carbolic acid in about ten parts of olive oil answers well.[1] As an example of its use in this way, I may mention a practice which I have adopted of late years in caries limited to the middle or anterior part of the tarsus and accompanied by sinuses. Cutting right across the soft parts of the dorsum of the foot, including the tendons, vessels, and nerve, I open the tarsus completely from side to side at the diseased part, when, the foot being bent upon the sole as upon a hinge, the carious portions are exposed with perfect freedom for inspection and operation, and all bones or portions of bones that appear suspicious are removed, the procedure being rendered much more precise and satisfactory by the bloodless method of operating which I have for many years pursued—viz. emptying the limb of blood by raising the foot to the utmost for a few minutes, and then applying a tourniquet as rapidly as possible and so tightly as to prevent any circulation in it.[2] The vessels having been secured, it remains to dress the wound. If this were done in such a way as to permit unchecked putrefaction in it, there would be great risk of serious disturbance from the extension of putrefactive suppuration into the tarsal joints opened in the operation. On the other hand, as the sinuses communicating with the wound already contain putrescent materials, it would be useless to operate under the spray and apply an external gauze dressing.

[1] Linseed oil is objectionable from the permanent staining it produces in linen. Boiled linseed oil is, indeed, far better than any other oil for mixing with whitening and carbolic acid to form the antiseptic paste or putty, which has long since been superseded by the gauze, but which on an emergency, in absence of the gauze, might still be used with advantage in some cases.

[2] Since Professor Esmarch has published his method, I have substituted an india-rubber tube for the tourniquet with advantage.

What is needed is something that shall prevent the putrefaction from spreading from the points where it may exist to the rest of the wound. This object is attained by first washing the cut surface with the solution of chloride of zinc, 40 grs. to 1 oz. of water—a practice of the utmost value in all cases where, in consequence of the presence of sinuses or the situation of the part, as the mouth or perineum, it is impossible to exclude causes of putrefaction from the wound. When sinuses are present, I formerly advised their injection with solution of the chloride by means of a syringe before the commencement of the operation. But though this is undoubtedly the most efficient mode of introducing the liquid into the recesses of the sinuses, I have found that the force with which the solution is driven in by the syringe may cause it to burst through the pyogenic membrane of the sinuses and become effused into the cellular tissue. This accident, in two instances (one of caries of the wrist and one of amputation through the condyles of the femur) led to extensive loss of vitality of the integument, and hence for the last three years I have contented myself with injecting the sinuses at the conclusion of the operation, when, the sinuses being freely open at the wound, the risk referred to no longer exists.

Chloride of zinc, I may remind the reader, has this remarkable peculiarity among all antiseptics that I have tried, that a single application of it to a recent wound in a solution of the strength above mentioned, though it produces no visible slough, yet prevents the occurrence of putrefaction in the cut surface for days together, in spite of the access of septic material; [1] and if the discharges have opportunity to flow freely away, as after the removal of a tumour of one of the jaws or a portion of the tongue, there may be absolutely no odour from first to last, the divided textures being thus guarded from the bad effects of putrefaction during the dangerous period before they have been covered by the protecting layer of granulations.

But in the wound of the foot which we are considering, if any permanent dressings were employed, the blood and serum effused in the early periods of the case, and accumulating more or less in the interior, would not be prevented from putrefying by the chloride on the cut surface. And it is only in rare cases that the injection of the sinuses with the chloride has the effect of eradicating all putrefaction from them. This is a thing to be aimed at, but hardly expected. In order, therefore, to avoid the extension of putrefaction from any septic point in the wound, the antiseptic dressing must be frequently changed; and this is conveniently done with pieces of lint dipped in the oily solution of carbolic acid (1 to 10), the oil preventing the lint from sticking in the wound, so that it

[1] For the introduction of this invaluable antiseptic into surgical practice the profession is indebted to Mr. Campbell De Morgan, of the Middlesex Hospital, London.

can be readily removed. In order to admit of the free application of this dressing to all parts of the cut surface, the wound is made to gape freely by depressing the toes along with the foot-piece of the M'Intyre splint on which the limb rests. The oiled lint is renewed every three hours day and night during the first twenty-four hours, and after this the interval is gradually increased as discharge diminishes, till after three or four days one dressing per diem is sufficient. The free exposure of the wound has this further important advantage, that it permits the surgeon to examine the surface with the finger from time to time in order to ascertain when the bones are entirely covered with soft granulations; for then and not till then can he be sure that the bones are perfectly sound, and as soon as this is the case the foot-piece is adjusted at right angles with the leg, so as to permit the granulating surfaces to coalesce and the wound to heal. In all the five cases in which I have hitherto had occasion to employ this treatment, the immediate object was completely attained, the foot remaining quite free from inflammation, and the constitution without febrile disturbance. Two of the cases are still under treatment, not yet completely cicatrized. Of the other three feet operated on in this way, two are useful and strong, though more or less shortened. The other, after being a perfectly serviceable foot for several months, became the subject of relapse, requiring amputation at the ankle. The practice was suggested to me by the remarkably satisfactory results of antiseptic treatment in a case of wound by a circular saw which divided the soft parts completely at the instep, laying the ankle-joint freely open. The patient not only recovered with a freely movable ankle-joint, but, except a line of cicatrix across the instep, there was nothing abnormal in either the appearance or actions of the foot. And it is somewhat remarkable that, in the cases of disease, where the wound has been left gaping for weeks, not only has the power of extension of the toes been restored, but sensation has been recovered in the parts supplied by the divided nerve.

As another example of the usefulness of the oiled lint may be mentioned abscess beside the rectum, where the vicinity of the anus renders a permanent gauze dressing inapplicable. The skin having been washed with 1 to 20 watery solution of carbolic acid, the abscess is opened under the spray where it points, and a pad of lint soaked with 1 to 10 carbolic oil[1] is applied and retained by a T bandage, and changed every five or six hours. Before defecation, the patient draws the bandage and pad towards the side where the wound is, so as to keep the latter covered while exposing the anal outlet, which is carefully cleansed with a piece of lint dipped in the antiseptic oil before the pad is readjusted.

[1] Lord Lister afterwards substituted glycerine for oil as the vehicle for the carbolic acid in the dressing; the anus being cleansed, on exposure, with the watery solution.

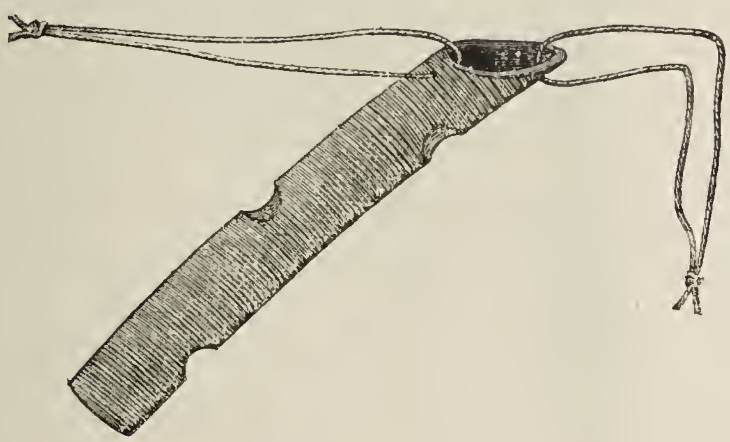
The oil, penetrating among the folds of the skin, is more efficient for this situation than the gauze would be, even were it frequently changed. After two or three days have passed, the strength of the oil may be reduced to 1 to 20, if the stronger proportion causes irritation. I have treated several cases in this way both in hospital and in private practice, and in every instance the occurrence of fistula has been avoided, although in some of them it was ascertained, by digital examination of the rectum before opening the abscess, that pus was present in the submucous tissue—a state of things which, I believe, inevitably leads to fistula if the abscess is treated in the ordinary way. Of course scrupulous care on the part of the patient is essential to success, but this I have not found wanting, even in hospital cases, when it is clearly explained that fistula will be prevented by the requisite pains.

It is an interesting fact, pathologically, that the progress has been equally satisfactory when the pus has been fetid on evacuation as when it was odourless, the discharge being a mere serous oozing after the escape of the original contents. This seems to imply that the cause of the fetor was not any organic (bacteric) ferment, but a peculiarity in the action of the part. For had septic organisms been present before the abscess was opened, they would have continued to propagate in it in spite of the antiseptic treatment ; and the result would have been the same as under poultice or water dressing, or, what comes to the same thing, under an antiseptic dressing carelessly employed. For it is hardly needful to point out that neither the spray nor the carbolic oil applied externally, nor the oiled lint inserted in the outlet to serve as a drain, could correct putrefactive fermentation once established in the abscess cavity. Here, as in the antiseptic treatment generally, the means used are calculated to prevent, not to correct, putrefaction.

In the case of abscess beside the rectum a bit of lint soaked with carbolic oil is used for a drain, simply because in this situation it is not easy to keep in position a caoutchouc drainage-tube, which, under ordinary circumstances, is greatly to be preferred, since it does not at all obstruct the flow of discharge, and may be carried to any depth that is desired, and can be removed and reintroduced without difficulty. Hence a drainage-tube of comparatively small size introduced through a mere puncture in the skin, or through a small interval between stitches, is more efficient than a free incision or a widely gaping wound without the use of a tube. The tubes should vary in size in proportion to the quantity of discharge anticipated, from the thickness of a crow-quill to that of the little finger, and the holes in them should have a diameter about half that of the tube. The outer end of the tube should be on a level with the skin, and it is conveniently maintained in this position by means of two pieces of silk passed with a needle through two opposite points of the edge of the tube,

the ends of each thread being knotted at a distance of one or two inches from the tube. These knotted threads being placed straight upon the skin, one at each side, the knots exert friction upon the dressing bound down upon them, and prevent the tube from being pushed in, while the dressing itself keeps it from protruding, so that the orifice lies flush with the integument. When the tube has to be placed obliquely, its outer end must be cut obliquely in proportion, as shown in the accompanying sketch, otherwise it is apt to become partially buried and blocked up.

Another cause may lead to partial obstruction in chronic cases, such as spinal abscess—viz. the projection of fungoid masses of granulations through the holes in the tube so as to interfere with its calibre, and at the same time cause difficulty in extracting and reintroducing it. But this inconvenience is got over by having the holes restricted to the vicinity of the deeper end of the



tube: for it seems to be chiefly at and near the integument that the granulations have this tendency to fungate; and in cases of this kind it is only at the deeper part of the tube that holes are required.

In recent wounds I used to think it needful to take out the tubes on the day after operation or accident to clear them of clotted blood. But I find this is wholly unnecessary, the shrinking of the clot apparently preventing it from interfering with the exit of discharge, so that a tube introduced at the time of an operation may be left in for three or four days, by which time the tissues around it will have been consolidated by organizing blood or lymph into a smooth channel, into which the tube can be readily reinserted, which is by no means always the case if it is taken out the day after operation.

In large and deep wounds, where very free drainage is required, it is convenient, instead of using one tube of very large calibre, to insert several of smaller size side by side. These, while quite as efficient as a single large one, do not separate the edges of the wound so much, and they can be afterwards withdrawn one after another as the discharge becomes reduced.

It is impossible to exaggerate the importance of drainage-tubes. In abscesses they must be employed till the cavity is completely closed; and in wounds not only are they invaluable during the first twenty-four hours, when the irritation caused by the action of the antiseptic on the tissues during an operation renders the flow of bloody serum more free than it would be without antiseptic management; but when the wound is of any considerable depth they should be used so long as even trifling serous oozing continues. For if the outlet proves insufficient for the free escape of the plasma still effused into the interior, the fluid, accumulating in the cavity, gives rise to tension, and hence to inflammatory disturbance, which may lead to suppuration and more or less opening up of the wound.

As an illustration of the value of drainage-tubes in the later stages of the treatment of wounds I may take a case of popliteal aneurysm in which I tied the femoral artery last summer. The patient, a man thirty-eight years of age, who had been a soldier, was admitted into the Royal Infirmary on the 16th of June, with a swelling about as large as an orange in the left ham, with expansile pulsation and thrill, and other signs of aneurysm; and he stated that the swelling had appeared suddenly five months previously, as he was sitting with his legs crossed, accompanied by a throbbing sensation, which had since continued to increase. The left leg was very weak, and was occasionally affected with darting pains, and the foot was somewhat oedematous. He had a worn, cachectic aspect, and the stethoscope indicated the presence of valvular disease of the heart, both at the mitral and the aortic orifice. Believing that, brilliant as are the results often obtained by compression, the patient's interest will on the average be best consulted by at once tying the femoral artery antiseptically, provided that the catgut be thoroughly trustworthy, and that the operation and after-treatment be really so conducted as to secure absence of putrefaction in the wound, I applied a ligature on the 24th of June, turning aside the edge of the sartorius so as to gain access to the vessel four inches and a half below Poupart's ligament, the situation which Mr. Syme used to advise in order to ensure a sufficient distance of the point of deligation from any considerable arterial branch; though indeed the antiseptic treatment seems to render this consideration of comparatively little importance, a fact which this case itself will be found to exemplify. The catgut employed was more substantial than that commonly used for tying vessels in wounds, being rather more than one-fiftieth of an inch thick. It had been prepared by myself more than a year before by the method described elsewhere,[1] and as the quality of the gut improves the longer it is retained in the preparing liquid, I knew that this specimen was

[1] See Holmes's *System of Surgery*, second edition, vol. v, p. 622.

thoroughly trustworthy. The ends of the gut were cut off near the reef-knot in which it was tied. The operation was performed under the spray, and with such precautions as the germ theory dictates.

And here I may take the opportunity of enforcing one of these precautions, which I observe is apt to be overlooked. If a knife or other instrument, after being used during an operation, is temporarily set aside or even withdrawn for ever so short a time from the antiseptic atmosphere of the spray, it must be cleansed afresh with carbolic lotion, whether by means of a sponge or by rubbing it in the spray near the nozzle of the apparatus, where the liquid is little mixed with air, otherwise septic material mingled with the blood on the instrument, failing to be purified by merely passing rapidly through the spray, may be carried in an active condition into the depths of the wound. This is one of those essential points which I believe nothing but a knowledge of the great importance of avoiding putrefaction and a lively sense of the presence of septic ferments diffused in the world around us [1] will enable the operator to keep vigilantly in mind.

The edges of the incision were brought together by carbolized silk sutures,[2] except at one part, where two drainage-tubes of rather small calibre were placed side by side, communicating with the deepest part of the wound, and the gauze dressing was applied as usual with a strip of oiled silk protective over the line of incision, and the patient being put to bed, the foot and leg were enveloped in cotton-wool. Next day, the dressing, being changed, was found extensively stained with bloody serum, but there was no inflammatory blush or febrile disturbance. On the following day the wound was again dressed, and one of the drainage-tubes was removed. The spray was of course used in changing the dressings, and I may remind the reader that it is of especial importance that it be fairly directed on the wound during the withdrawal of a drainage-tube, the place of which must necessarily be taken by air, which, if not purified by the spray, will be likely to be septic.

The wound being exposed again after an interval of two days, the stitches were found to be causing a little tension, and were therefore all removed; but

[1] If any one chooses to assume that the septic material is not of the nature of living organisms, but a so-called chemical ferment destitute of vitality, yet endowed with a power of self-multiplication equal to that of the organism associated with it, such a notion, unwarranted though I believe it to be by any scientific evidence, will in a practical point of view be equivalent to the germ theory, since it will inculcate precisely the same methods of antiseptic management. It seems important that this should be clearly understood, because it appears to be often imagined that authors who are not satisfied of the strict truth of the germ theory, but substitute for it the other only possible hypothesis, invalidate the antiseptic practice, which, I must repeat, is not affected in one tittle by this theoretical discrepancy.

[2] Prepared by immersing a reel of the silk in melted bees-wax mixed with about a tenth part of carbolic acid, and drawing the thread through a dry cloth as it leaves the liquid, to remove superfluous wax.

the temperature was normal, and the serous oozing diminishing. Two days later, or six days after the operation, the pain in the limb, of which he had complained at the last dressing, had left him ; but a considerable serous stain being still found on the gauze, the drainage-tube was continued, though shortened by cutting off a piece from the deeper end. Eight days after the operation the cotton-wool was removed for the first time from the leg and ham. The foot was free from oedema, and otherwise natural in appearance, and the aneurysmal tumour had become greatly reduced, being now only a flattened mass about one inch and a half across, free from pulsation. All trace of the jerking pain he had in the limb before the operation had left him, and his general appearance was much improved on what it was on admission. The wound being dressed, the line of incision was found entirely healed, except at the point occupied by the drainage-tube, and the serous stain on the dressing was so much diminished that I reduced the little tube to a quarter of an inch in length, and allowed three days to pass before the next dressing. On then exposing the wound, however, I was disappointed to find the serous stain on the gauze fully as great as on the last occasion, and pressure on the skin in the vicinity of the wound caused a drop of clear serum to escape. This had never been seen before, and implied that the shortened drainage-tube had not been answering its purpose completely, but had permitted a certain amount of serum to accumulate ; and slight as this accumulation was, I knew from experience that it was enough to perpetuate serous oozing by the tension which it occasioned. I therefore substituted for the short drainage-tube another of the same calibre, but twice as long—viz. half an inch, being as deep as it could be passed without violence, and dressed again in two days. The result was such as I hoped. There was an almost entire absence of serous stain on the gauze, and nothing could be pressed out of the tube, which was now again slightly shortened. The dressing was then left untouched for four days, when the drainage-tube was found lying out of the wound, having been forced out by the consolidation going on in the interior. There was almost no stain upon the gauze, and nothing could be pressed out of the orifice where the tube had been. It was therefore finally abandoned, and by the 19th of July, twenty-one days after operation, the dressing being changed after an interval of six days, cicatrization was found to be complete, not a drop of pus having appeared from first to last.

So late as the 13th of July, seventeen days after the operation, or at a later period than that at which a silk ligature applied without antiseptic means commonly separates, pulsation could be felt in the femoral artery as low down as the junction of the middle and lower thirds of the incision ; or, in other words, down to the very site of the ligature. It appeared, therefore, that some

branch of unusually large size must have taken origin so close to the part tied as to prevent entirely the formation of a superior coagulum ; and it is probable that with an ordinary ligature the case might have terminated disastrously from secondary haemorrhage. Thus we seem to have here an example of the safety of the antiseptic ligature in the vicinity of a considerable arterial branch.

But to return to the point which this case is intended to illustrate—viz. the value of the drainage-tube in the later stages of the treatment of wounds. Supposing that instead of substituting a longer tube for the shorter one on the eighth day after the operation, when a little serum was found to have accumulated, I had then given up the use of the tube altogether, the probability is that by the time of the next dressing, the outlet at the integument having become partially occluded by granulation and contraction, a greater amount of serum would have been pent up in the cavity, and that in course of time the additional tension so occasioned would have led to suppuration and to the opening up of the nearly cicatrized wound.

The effect of an accumulation of serum in keeping up inflammatory disturbance, and the usefulness of the drainage-tube combined with antiseptic management under such circumstances, are well exemplified by chronic bursitis patellae, with fluid effused into the sac. The skin being washed with 1 to 20 carbolic lotion, a puncture is made under the spray with a tenotomy knife, sufficient for the introduction of a drainage-tube scarcely larger than a crow-quill, care being taken that it penetrates fairly into the cavity of the sac, which often lies at a considerable depth in consequence of thickening of the membrane and of surrounding textures. The narrow drainage-tube may be readily inserted by means of a simple modification of the dressing forceps introduced by myself several years ago, but hitherto unpublished. The blades, which are straight, are ground down to the size of a probe at their extremities, as shown in the accompanying sketch (p. 222), so that they can be passed into a very small orifice. This instrument, which goes by the name of sinus-forceps among the Edinburgh instrument-makers, will be found very useful for extracting small exfoliations and for various other purposes.

The clear fluid contents being all pressed out of the sac, a gauze dressing is applied, and retained in position with a figure-of-8 bandage. The dressing being changed next day, the gauze is found considerably soaked with serous discharge, but, if the tube is acting efficiently, nothing can be pressed out of the cavity. And it will very likely be found that the end of the tube is projecting slightly above the level of the skin, and cannot be pushed in again to its original position, so that it is necessary to shorten it a little. This depends on the fact that, even within twenty-four hours of the opening of the sac, the

chronic thickening of the textures has markedly subsided. The same thing will be probably still more apparent when the dressing is again changed after forty-eight hours more, when also the serous stain on the gauze resulting from two days' discharge will be only a small fraction of that seen after the first twenty-four hours. The tube being further shortened to the requisite degree, the dressing now applied might be left untouched for a week so far as regards the purpose of ensuring absence of putrefaction; but it will be well to expose the part again in two or three days in order to ascertain whether or not the drainage-tube may be dispensed with; the rule being that it should be continued so long as the serous stain on the gauze is more than the puncture, as distinguished from the interior of the sac, would account for. This is probably the case within a week of the opening of the bursa; and then, the drainage-tube being discontinued, and a small piece of protective being interposed between the puncture and the gauze so as to permit cicatrization, the little sore will be found completely healed in the course of another day or two. At the same time the sac will be free from any fluid accumulation, and the surrounding thickening either quite gone or quickly disappearing.

While we have thus a sure, speedy, and (except the infliction of the puncture) a painless[1] method of remedying a troublesome complaint, the results are of considerable theoretical interest. It is plain that the antiseptic employed does not penetrate into the bursa, so as to exert any direct action on the part affected. All that the treatment does is, while guarding against the access of putrefactive fermentation, to provide that the plasma poured out from the synovial surface shall flow freely away as fast as it is effused and never accumulate in the cavity. Yet when these conditions are complied with, the obstinate chronic inflammation, which has perhaps already resisted rest and counter-irritation, immediately proceeds to subside, the morbid tendency of the synovial membrane is soon entirely lost, and the surrounding inflammatory thickening is

[1] If it be desired, the puncture may be performed painlessly after congelation of the integument by Richardson's method with ether spray, the skin being washed with the carbolic lotion before freezing, and the antiseptic spray substituted for the anaesthetic before the tenotome is introduced.

dispersed. It follows, therefore, that the presence of the fluid within the sac was of itself sufficient to perpetuate for an indefinite period the state of chronic inflammation. And this fluid being the bland liquor sanguinis, perfectly destitute of chemically irritating qualities, the only possible way in which it could have produced its effect is by mechanical disturbance occasioned by its presence in the sac. In other words, the agency by which the chronic bursitis was maintained was that which, next to putrefaction, is the commonest of all causes of inflammation in surgical practice—viz. tension. Yet, in cases of this kind, the sac is by no means always extremely distended; but, flaccid though it may be, the fluid present in it keeps up by its mechanical influence the tendency to abnormal effusion from the synovial surface and inflammatory hypertrophy in the surrounding tissues. It seems to me important that this point should be capable of being thus clearly demonstrated; because the knowledge that a flaccid collection of liquid acts as a cause of disturbance not only serves to explain the obstinacy of chronic serous and synovial effusions, but throws light upon other important matters, such as the prejudicial effect of even a slight accumulation of serum within a wound, as in the aneurysm case above related, or the influence of the presence of the contents of a slack chronic abscess in maintaining suppuration from the pyogenic membrane. And, conversely, this knowledge enables as to understand the benefit often obtained by simply evacuating serous or purulent collections, either as a single remedial measure or as a preliminary to counter-irritation.

When the evacuation is effected in such cases by means of the aspirator, the piercing cannula should be dipped into carbolic oil before introduction. And if, as is often the case, the narrow tube becomes obstructed by lymph or curdy material, there is no objection whatever to the use of an ordinary cannula and trocar of any size that may be necessary, provided that the instruments be smeared with the antiseptic oil and the operation be performed under the spray. In abscesses, however, according to my experience, a cure rarely results from evacuation of the contents by an opening which is allowed to close. The plasma which exudes from the pyogenic membrane after withdrawal of the pus will, if retained, nearly always occasion sufficient tension to reproduce suppuration. But if it be allowed to flow freely away through a drainage-tube, under an antiseptic dressing, the pyogenic membrane being freed from the disturbing cause which urged it to perpetual suppuration before the abscess was opened—viz. inflammatory excitement occasioned by tension (greater or less according to the degree of acuteness of the case), while the granulating sac is protected from the new stimulus to which it would be subjected if the abscess were opened without antiseptic measures—viz. the chemical irritation of putrefying material—

the beautiful sight is witnessed of cessation of suppuration from the moment that the original pus is evacuated, the serous discharge diminishing constantly till the abscess cavity is closed.

If antiseptic treatment had done nothing more than create such a revolution in the treatment of abscess and throw such light upon its pathology, it would have well deserved the gratitude of the surgeon.

But in order that such results may be obtained, it is necessary that both the above conditions be complied with—viz. a perfectly free outlet for discharge, and thoroughly efficient antiseptic management from first to last. If the former condition be not fulfilled, inflammatory suppuration from tension will occur; or if the accumulation of fluid be only to a very slight extent, increase or persistence of serous oozing will be the result. And if the latter essential fail to be maintained—as, for example, through inefficiency of the retaining bandage, allowing the dressing to become loose or displaced, or through the antiseptic treatment being given up too early, before the sinus has completely closed—septic suppuration will take place, with its various consequences, such as free incisions and counter-openings, or, in vertebral or articular disease, disaster varying according to the circumstances of the case.

A sponge wrung out of a strong watery solution of carbolic acid (1 to 20) forms a valuable aid to the drainage-tube in preventing, during the first twenty-four hours, the accumulation of blood in wounds having a considerable cavity, such as those left after the removal of tumours.[1] The wound having been stitched and the drainage-tube (or tubes) inserted, a strip of oiled silk protective is laid along the line of incision to keep it moist, and so prevent the sponge from adhering. A soft sponge, large enough to cover the entire cavity of the wound and purified as aforesaid, is then applied, and over it a gauze dressing sufficiently extensive to reach several inches beyond the sponge in every direction. The whole is retained in position by a pretty firm bandage, so as to bring into play the elasticity of the sponge, which keeps the surfaces of the wound in apposition, and, while checking sanguineous effusion, compels that which does occur to escape by the drainage-tube, when it is at once sucked up by the sponge as it oozes from beneath the protective.

If any one desires proof of the potency of a strong watery solution of carbolic acid to deprive septic ferments of their energy, he cannot do better than consider the results of this mode of dressing. The same sponges are used over and over again till they wear out, and for hospital purposes they are kept always steeping

[1] The sponge had long been a favourite application of Mr. Syme's under such circumstances, and he was the first to use it antiseptically. The case was one of very large parotid tumour, in a woman advanced in years; and the dressing employed was a large sponge squeezed out of carbolic oil, which answered its purpose admirably.

in the carbolic lotion. But in private practice the plan which I have pursued for several years is the following: The sponges, after being used for an operation, are put into a vessel of water and left there till the fibrine in their pores has been converted by putrefaction into a slimy liquid which can be readily washed out. They are then squeezed in successive portions of water till they cease to discolour it, and, after having been well wrung, they are thoroughly moistened with the 1 to 20 watery solution of carbolic acid. The sponges after being so treated have, very likely, a decided putrefactive odour clinging to them; but this is a matter of no moment. The presence of a little of the *products* of putrefaction will do no harm if the *causes* of the fermentation have been destroyed. And that such is the case is evident from the following considerations: The sponge, being squeezed as dry as possible when applied, contains but little of the solution of carbolic acid with which it was treated, and this is soon displaced from the parts next the wound, or at least copiously diluted by the effused blood and serum, which are often in such quantity that the red liquid can be wrung out of the sponge when it is removed on the following day. If, therefore, any septic ferment were present in an active state in the deeper parts of the sponge, the bloody serum could not fail to putrefy, since there is certainly not a sufficient proportion of carbolic acid mixed with it to act as an antiseptic. Yet, in point of fact, putrefaction never does occur in the sponge (provided, of course, that all the proceedings have been, in other respects, conducted antiseptically), and I cannot call to mind a single instance of such an occurrence either in private or hospital practice. It follows that no active septic ferment is present in the portions of such a sponge which become soaked with the serum. Yet before the sponge was treated with the solution of carbolic acid it contained such ferments in abundance; for, not to speak of the residual putrid material left after the often hasty and imperfect washing, the very water with which it was washed teemed with septic ferments, as was clearly demonstrated some years ago by Dr. Burdon Sanderson.[1] How, then, had they been got rid of? They could not be all washed out like the carbolic acid, because, as will be shown in the next paragraph, they are not matter in solution, but solid particles, which must remain entangled in abundance in the porous material of the sponge. The only other possible way in which they can have been disposed of is by the action of the carbolic acid upon them. And thus we are led inevitably to the conclusion that this agent, applied in the form of a strong watery solution, completely and permanently extinguishes the septic energy of putrefactive ferments.

That the septic ferments are solid particles, not material in solution, might

[1] See Dr. Sanderson's paper in the *Quarterly Journal of Microscopical Science*, 1871.

be pretty safely assumed from analogy, if it were granted that they are living organisms; though, indeed, I once heard it propounded in conversation by a very sound and eminent chemist that, for aught we could tell to the contrary living matter in its lowest forms might exist in a soluble condition—an idea suggested by Dr. Sanderson's statement that a drop of water in which no bacteria could be discovered by the microscope will nevertheless give rise to the development of such organisms when added to a liquid adapted for their growth. But those who hold that the septic agents are not organisms at all, but so-called chemical ferments, might with greater justice contend for their possible solubility. The point being of great practical as well as speculative interest, I have been glad to obtain conclusive evidence regarding it from some simple experiments lately performed, and hitherto unpublished. I must content myself on the present occasion with briefly indicating their character.

A series of experimental glasses, contrived so that their contents shall be securely protected from dust, though the atmospheric gases gain free access to them, having been purified by heat, are charged with some liquid, like boiled milk, favourable for organic development and prone to fermentative changes, but uncontaminated at the outset by the presence of any living organism.[1] If the glasses so arranged are left undisturbed, the liquid remains unaltered for an indefinite period, except that its bulk is slowly diminished by evaporation. But if a minim of ordinary drinking-water is added to any one of the glasses, its contents will in a few days be obviously altered in chemical character, and before long will probably be decidedly putrid, the microscope at the same time revealing abounding bacteria—a result in perfect accordance with Dr. Sanderson's observations. If, however, instead of an entire minim, a small portion (say a hundredth) of a minim of the same water is added to each of a series (say ten) of such glasses (which can be readily done by means of a small syringe,[2] having its piston-rod in the form of a fine-threaded screw, on which a graduated disc revolves to regulate the amount of liquid emitted from the slender glass tube that constitutes the nozzle of the instrument), a very different result ensues. Some of the glasses probably remain permanently unchanged, as if nothing had been added to them; and those which do experience alteration show plainly, by differences of colour and of smell, that they are undergoing various kinds of fermentation, while the microscope shows corresponding differences in the characters of the bacteria found in them.

It is hardly needful to remark that if the ferments were dissolved in the

[1] For an account of the manner in which these conditions are fulfilled see a paper by the author entitled 'A further Contribution to the Natural History of Bacteria', &c. (*Microscopical Journal*, October 1873). (See vol. i, p. 309.)

[2] See vol. i, pp. 364–5.

water they would be equably diffused through it, and the same effects would be produced in all the glasses by the addition to each of the same quantity, however small. It is thus conclusively shown, so far at least as regards the fluids which I have hitherto made the subjects of experiment, that the material in water which leads to putrefaction or other fermentative changes in an organic liquid is not in a state of solution, but in the form of suspended particles, various in kind and, though present in great numbers, by no means equably diffused, but scattered through the water at various distances, like the amoebae or other animalcules which people it. This will, I believe, be found to be a sure and important step in proof of the theory upon which the antiseptic treatment is based. But a practical paper like the present is perhaps hardly the proper place for discussing its bearings in this respect.

I have now to speak of improvements in our practice connected with the introduction of new antiseptic substances.

About three years ago my friend, Dr. Stang, of Sorweg, in Norway, being on a visit to Edinburgh, informed me that a new antiseptic had been discovered in Sweden, and was already extensively used in that country for the preservation of articles of food, and also as an application to wounds. The ‘ aseptin ’, as it was termed, was in two forms, a powder and a liquid, the latter receiving the additional title of ‘ amykos ’. The composition of the preparations was kept secret ; but there was little doubt that they owed their virtue to one common ingredient ; and he promised to send me samples of them, in the hope that they might prove useful in carrying out the antiseptic principle in surgery. This promise he at once fulfilled on returning home, at the same time telling me that the active principle of both the articles had been ascertained to be boracic acid, the virtues of which had been discovered by Mr. Gahn, a chemist in Upsala.

It happened that I was just then suffering from onychia of the little finger, attended with excessive fetor, and at the same time exquisitely sensitive, so that even a very weak watery solution of carbolic acid caused almost intolerable pain, while it entirely failed to subdue the pungent ammoniacal odour. I at once gave a trial to the amykos, using it just in the same manner as the former lotion, dropping some of the liquid upon the tip of the finger and wrapping it in lint soaked with the same fluid and covered with gutta-percha tissue. The drops of the amykos, as they fell upon the sensitive surface, caused not the slightest twinge of uneasiness ; yet when I changed the dressing, after the usual interval, I was surprised to find an almost entire absence of fetor. Here, then, I had at once sufficient evidence that the new antiseptic, when employed in the form of watery solution, was both highly efficient and much less irritating than carbolic acid.

Boracic acid was then little more than a chemical curiosity. But I succeeded in obtaining in Edinburgh a sufficient quantity to enable me to test its properties unmixed with other ingredients. A striking instance of its antiseptic efficacy as well as of its therapeutic value was at once presented by a case of pruritus ani of upwards of ten years' standing. The affected part was washed with a saturated watery solution at bedtime, and a small piece of lint soaked with the same lotion was applied and retained during the night. The result was immediate relief from the accustomed irritation, and, what struck me as extremely remarkable, the bit of lint, when removed next morning, was free from smell. It was afterwards found that even the slight mechanical irritation caused by the presence of the lint might be avoided ; for the mere application of a few drops of the watery solution last thing at night, the part being left moist with the liquid, proved completely efficacious ; and this simple treatment being continued for a while, the obstinate tendency to irritation gradually disappeared, while the thickening of the folds of skin, which had been of several years' duration, entirely subsided.

Another example of the usefulness of the new remedy was furnished about the same time by a case of inveterate eczema of the ankles in a lady above the middle period of life. The water dressing which she used being removed, a very unusually fetid odour was exhaled from the moist scarlet surface, which, tender as it was, she was impelled to scratch by an intolerable sense of itching. Thinking that here, as in the case of pruritus, the irritation caused by putrefaction might be a main element in the obstinacy and discomfort of the complaint, I gave the boracic acid a trial, substituting a saturated watery solution for the water in the dressing previously employed. The effect was at once to correct the fetor, but in this case the application occasioned a good deal of persistent uneasiness in the sensitive surface. The patient, however, persevered with the treatment, and in a short time the ankles were both in a sound condition, which I was lately glad to learn had proved permanent.

But, striking as were these evidences of the antiseptic virtue of boracic acid, I knew well that in the form in which I had hitherto tried it—namely, in lint soaked with a watery solution—it could not answer for a permanent antiseptic dressing under circumstances where there is at all a free discharge. For the putrescible fluid soaking into the lint would drive the antiseptic before it, and occupy its place, and as soon as this had occurred throughout the thickness of the dressing at any one point, putrefactive fermentation would be free to spread into the wound. In order that the dressing might be trustworthy it was necessary that the boracic acid should be in some way stored up in it, as carbolic acid is in the resin of the gauze, so that it could not be at once washed

out from it by the discharge. A ready means of attaining this object was presented by the fact that the acid, though but sparingly soluble in water at ordinary temperatures, is pretty freely dissolved at the boiling-point. Thus, at 60° Fahr. water takes up only about a twenty-sixth part of its weight, and at 100° less than a sixteenth, but at 212° more than a third. Hence if a piece of lint is dipped in a saturated solution near the boiling-point, it absorbs a great deal of the acid, and, after being allowed to dry, it is found to weigh about twice as much as it did originally, the weight of the crystals disseminated through it being nearly equal to that of the lint itself. If, therefore, this 'boracic lint' is used as a dressing the discharge may soak through it repeatedly without dissolving out all the acid, although it takes up in its passage a sufficient amount to render it antiseptic. It is further a fortunate circumstance that the crystals of boracic acid, instead of being hard and harsh, like most crystals, are soft and unctuous, and therefore occasion no mechanical irritation of the skin.

The boracic lint has proved very valuable in the treatment of ulcers of the legs or elsewhere. In dealing with them, the first step is to cleanse the sore and the surrounding skin once for all from septic impurity. This is done by treating the surface of the sore freely with a solution of chloride of zinc (forty grains to the ounce), and at the same time washing the integument with a strong watery solution of carbolic acid, which is used on account of its remarkable power of penetrating the epidermis, while for the sore itself the solution of the chloride appears to be more efficient. This preliminary step having been taken, the boracic dressing is at once employed as follows: A piece of oiled silk protective, of sufficient size to cover the sore and slightly overlap the surrounding skin, is dipped in the boracic lotion (a saturated watery solution) and applied, and over this a piece of boracic lint large enough to extend for an inch or more beyond the protective on all sides, the whole being retained in position with a bandage. It is well to soak the boracic lint with the lotion before putting it on, not for the sake of adding more of the acid, but because the lint, when applied moist and allowed to dry on, is less liable to slip afterwards from its position, and also for the purpose of purifying the surface of the lint itself, which in the dry state has no power of acting upon septic dust adhering to it, the acid which it contains being non-volatile, and, therefore, only acting when in solution.

In this dressing the protective serves its usual purpose of preventing as much as possible the direct action of the antiseptic upon the healing part; and although boracic acid interferes with cicatrization much less than carbolic acid does, the epidermic development proceeds more quickly when it is excluded, while the formation of pus due to the stimulation of the surface of the granula-

tions by the acid (antiseptic suppuration)[1] is of course diminished ; and the less the discharge, the less frequently is it needful to change the dressing. The protective also keeps the surface of the sore moist, and so prevents the discharge from being pent up and causing inflammatory disturbance from tension, as is apt to be the case beneath the crust of inspissated pus in a dry dressing. The lint is also kept from sticking to the sore and tearing off the newly formed epidermis when it is removed.

But it must always be remembered that the protective, in proportion to the efficiency with which it discharges its function of preventing the irritation of the acid, excludes also its antiseptic virtue, so that if putrefactive material exists beneath it at any one point, the septic fermentation will spread over the whole sore. Hence the necessity for having the boracic lint to extend on all sides beyond the oiled silk, for if the protective were to escape at any one place from under cover of the antiseptic layer, it would necessarily conduct putrefaction inwards beneath it. Hence also the importance of adopting thoroughly efficient means of purifying the sore as a preliminary measure.

But if those points are attended to, this mode of dressing will be found to yield excellent results. The epithelial development, protected from needless disturbance, proceeds at a rate altogether unknown under water dressing, and cicatrization will often advance steadily in sores which, under ordinary treatment, cannot be got to heal at all ; as when, through the unyielding character of surrounding parts, the shrinking of a large granulating surface has put the imperfect textures of the sore upon the stretch, and thus so reduced their vital power as to make them liable to ulceration or sloughing under the influence of stimuli which fail to arrest the healing of an ordinary vigorous sore, such as solutions of astringent salts or the degree of putrefaction that occurs in water dressing within twenty-four hours. This application also saves trouble to the surgeon, for if properly used, it may be left unchanged for a period varying from two to five days, according to the amount of the discharge.

This last circumstance, together with the unirritating character of the dressing, makes it peculiarly useful for skin-grafting. The manner in which I have for a considerable time carried out Reverdin's beautiful principle is as follows : The skin of the inner side of the upper arm having been lightly washed with 1 to 20 watery solution of carbolic acid to purify its surface, a thin layer of the integument is shaved off with a very sharp knife, so as to take barely more than the epidermis, scarcely drawing blood or causing pain. The little shaving is placed upon the thumb-nail of the left hand, moistened with a drop of the boracic solution, and bits not bigger than pins' heads are successively

[1] See above, p. 149.

cut off and laid upon the surface with which they are to unite, by taking up each graft upon one side of the point of the knife and stroking the other side of the instrument upon the granulations so as to have the graft behind. Care must be taken that the deeper surface of the graft is placed downwards, but this is readily done from the fact that the shaving always curls up with the deeper aspect on its concavity.

It is an interesting pathological fact brought out by this mode of procedure, that the surface of healthy granulations is as prone to adhere to freshly cut perfect tissues as granulations are to coalesce with each other, or the sides of a recent wound to unite by first intention. The practice often followed of cutting beds in the granulations to receive the grafts, very inconvenient from the bleeding which it involves, is therefore wholly unnecessary. The several pieces of epidermis, of which twelve are furnished by a slice a sixth of an inch square, if simply applied to the uninjured surface of the sore, will probably be found to afford as many starting-points for cicatrization, provided that the granulations are healthy to begin with, and that all needless irritation of the grafts is avoided. As regards the former condition, it is a great mistake to wait till healing has considerably advanced, and the sore has become already stretched and weakened by its own contractions ; and, as regards the latter point, the avoidance of needless irritation, the stimulus of putrefying materials must be got rid of by thoroughly purifying the sore as a preliminary measure, while the irritation of the antiseptic itself is reduced to a minimum by the dressing employed. In order to make sure against septic contamination during the process of grafting, it is well to cover the sore as soon as it is exposed with a piece of muslin dipped in the boracic solution, and uncover successive portions for the application of the grafts. Then, as each graft is put down, it is covered at once with a small piece of protective dipped in the lotion, and at the conclusion of the process any parts of the granulating surface remaining exposed are covered in either by separate pieces of protective or by a general piece over the whole, as no harm is done by the layer being double. Boracic lint wrung out of the lotion, and well overlapping the surrounding skin, is then applied, two layers being used at the more dependent parts if the sore is large and much discharge expected, and a retaining bandage is put lightly on. This dressing is left untouched for two or three days ; and when it is changed, all the protective will be found to come off as one piece adhering to the lint, but not sticking at all to grafts or granulations, which are covered with a layer of pus or lymph. This being free from putrefaction or any other irritating property, there is no need to wash the surface of the sore, a process which might disturb the grafts ; but without any delay a fresh piece of dipped protective is applied, and over

it the moistened boracic lint, any crusts of inspissated discharge on the surrounding skin being afterwards washed away at leisure with the lotion. When the dressing is next changed, the red ring of youngest cicatrix will probably be already apparent around each white epidermic islet.

The trifling wound on the arm which furnished the grafts is treated, like the sore, with protective and boracic lint, and, if these be properly secured, a scar will be found in its place when the part is exposed after the lapse of a few days.

To be able thus to treat recent abrasions with a single application, which may be left undisturbed for an indefinite period, is often a matter of great convenience, especially in the case which so frequently presents itself where such superficial injuries are present as complications of simple fracture. Here, without antiseptic management, troublesome sores are liable to form, requiring frequent disturbance of the splints to gain access to them for daily dressing. But after washing the part with (1 to 20) carbolic lotion, and applying the dressing of protective and boracic lint, the abrasions may be dismissed from further consideration.

It is, of course, essential for the success of this dressing that it should be kept accurately in position. In the case of abrasion in fracture this is probably ensured by the presence of the splints, and in large sores upon the legs it is readily done by means of a bandage, especially one made of the antiseptic gauze, which, as before observed, is less apt to shift its place than a common cotton roller. But for small dressings in any situation, and especially about the face, where bandages cannot well be used, it will be found very convenient to fix the boracic lint by means of collodion applied to the edges of a piece of cotton cloth of open texture, sufficiently large to overlap the skin on all sides around the lint. The cloth used for making the antiseptic gauze answers the purpose very well, only it must be employed unprepared, because the resin and paraffin of the prepared gauze would prevent the ether of the collodion from evaporating. In absence of the unprepared gauze, a piece of ordinary rag may be used, if the edges are frayed out sufficiently to give the collodion a proper hold upon the skin.

The boracic lint may often be employed with great advantage as a moist application, soaked with the boracic lotion, and covered with gutta-percha tissue or oiled silk. Foul ulcers, coated with a layer of putrid slough or lymph, if dressed daily in this way, will probably soon assume healthy characters; and when this has occurred, a comparatively slight washing of the sore with the chloride-of-zinc solution will be sufficient for the final purification, preliminary to using the dressing with protective and dry boracic lint; whereas if the chloride is used at the outset, while the sore is covered with its foul crust,

a very energetic application is required, entailing hours of considerable uneasiness to the patient.

In deep burns, where from any cause the sloughs have been allowed to putrefy, the moist boracic lint will be found an excellent dressing. In a case lately under my care, the gluteal region having been extensively and deeply burnt, the vicinity of the perineum made it impossible to keep out putrefactive fermentation. Here accordingly a daily dressing of lint, steeped in one part of carbolic acid to thirty of olive oil, and covered with gutta-percha tissue, was employed ; but, in spite of this application, the air of the room was pervaded with a strong putrid smell. I therefore substituted for the carbolic oil a dressing of moist boracic lint, and, at my next visit, was glad to find the apartment free from unpleasant odour, although, the sloughs having not yet separated, the emanations would doubtless have been even more offensive than before had the previous dressing been continued. I was, therefore, now able to direct that the boracic lint should be changed only every other day, instead of having the patient disturbed and pained by a daily dressing. And, further, when the sloughs had separated, feeling sure that, by virtue of the boracic acid stored up in the lint, putrefaction would be less advanced in three days under it than it would have been in twenty-four hours under water dressing, I felt justified in allowing this still longer period of tranquillity.

This is a sufficiently striking illustration of the value of the boracic lint as a moist application in all circumstances in which putrid sloughs are present in parts superficially situated, so that the antiseptic can gain access to them. And while the boracic acid gradually dissolved out of the lint by the discharges has this powerful effect in diminishing or arresting putrefaction, it also generally allows cicatrization to proceed kindly in such parts as are already cleansed of sloughs, though the healing is not so rapid as where the direct action of the acid is excluded by protective over a purified sore.

If much inflammation is present around putrid sloughs, wet boracic lint applied to the sloughs, and a poultice outside this and extending over the whole inflamed integument, will be found to work extremely well. The boracic lint may be left undisturbed for twenty-four hours or more, while the poultice is changed as often as may be desired.

The moist boracic lint is also a convenient dressing after operations upon the penis. Here the frequent exposure of the part for the purpose of micturition makes it necessary to entrust the antiseptic management on each occasion to the patient himself, so that some very simple arrangement is indispensable. With this object a strip of the moist boracic lint may be wound round the organ and secured in position by a piece of thread or narrow bandage, so as to cover

the wound but leave the meatus urinarius free ; and outside this permanent part of the dressing a loose piece of the wet boracic lint is wrapped and covered with gutta-percha tissue. Then at each time of micturition the patient removes the outer piece of lint, and readjusts it at the conclusion of the act, after pouring over the part a little of the boracic lotion. The unirritating character of the solution of boracic acid to mucous membranes, which is a peculiar feature of this antiseptic, prevents any inconvenience to the urethra from such treatment, which at the same time affords perfect security against putrefaction, yet allows healing to proceed kindly.

The most frequent case of operations in this situation is that for phimosis. It is now about ten years since it was pointed out by Mr. Furneaux Jordan, of Birmingham, that sutures are unnecessary after this operation, and that, after notching the narrow ring of the preputial orifice at one or more situations according to its tightness, and slitting up the inner layer of integument which embraces the glans, to a sufficient degree to permit free retraction, all that is required is to employ a simple dressing and to make a point of having the glans freely exposed once in twenty-four hours ; the result being avoidance of the unseemly notch which the stitch, if it really answered its purpose, inevitably occasioned. Ever since the publication of this simple method I have invariably followed it, and, as a rule, with great advantage ; but not infrequently the attainment of the object has been seriously interfered with by inflammatory swelling. But if putrefaction, which is the main cause of disturbance after this operation, is prevented by the boracic dressing, the oedematous puffiness of the prepuce, otherwise so apt to give trouble, is almost entirely avoided, provided that the incisions have been made sufficiently free to allow the utmost facility of retraction. It is, however, essential to the success of the antiseptic dressing that the organ should be thoroughly purified at the outset, as by washing the interior of the prepuce and the glans at the conclusion of the operation with saturated watery solution of carbolic acid (1 to 20), completely removing any portions of epithelial accumulation adhering about the frenum and corona. A narrow strip of the boracic lint is then wound round the neck of the organ and the retracted prepuce, with the object of keeping the parts in this position, except once a day when the skin is drawn freely forwards and again retracted. But if, as is often the case, there is an insuperable tendency of the skin to slip forwards, the permanent dressing may be dispensed with, the general covering of boracic lint being alone employed, with very free use of the lotion after each act of micturition, together with complete retraction once in twenty-four hours.

The last case in which I was called upon to operate for cancer of the penis may be given as another illustration of the value of this dressing. The integu-

ment being, as usual, less implicated than the spongy and cavernous structures, I proceeded as in a modified circular amputation in a limb, dividing the skin sufficiently in advance of the deeper parts to form a covering for them, and cutting its margin in the shape of short antero-posterior semilunar flaps which might be accurately adjusted without puckering, the removal being completed by a transverse stroke of the knife after retraction of the loose investment. I next sought to carry out the valuable principle first suggested by the late Mr. Teale, of Leeds,[1] of endeavouring to obtain union by first intention of the mucous membrane and the skin, so as to prevent subsequent contraction of the orifice. I first slit up the urethra longitudinally at its inferior part for about a third of an inch from its transversely divided extremity in the stump, as advised by Teale, and then perforated the tegumentary pouch at its ventral aspect by a cut equal in length to that in the urethra, taking care that the two openings should exactly correspond in position, and stitched the edges of the hole in the skin accurately, with silver wire at the angles and horsehair along the sides, to the margins of the mucous membrane, paring off the angles of the latter so as to form an oblique oval orifice to the urethra. The edges of the little skin-flaps were now also brought closely together with horsehair stitches, except in the centre, where a drainage-tube of crowquill size was inserted to prevent tension from accumulating blood and serum. The operation was performed under the spray, after the skin had been cleansed with a 1 to 20 carbolic lotion. The vessels having been tied with fine catgut, moist boracic lint was carefully adjusted so as to cover the end of the stump, but leave the urethral orifice exposed; and outside this permanent dressing a loose piece of the wet boracic lint was wrapped and covered with gutta-percha tissue, tied with the split end of a bandage which encircled the pelvis. This outer dressing was of course removed by the patient for micturition, and readjusted after washing with boracic solution; but the deep dressing was left untouched for two days, when it was taken off, entirely free from urinous odour, and, the drainage-tube having been taken out, fresh boracic lint was applied in the same way. The wound was again inspected two days later, and, as there was not the slightest inflammatory blush, and the stitches were evidently occasioning no tension, they were left undisturbed for three days longer, when they were found still lying in their places as they were after the operation a week before, and on their removal the cutaneous and mucous surfaces were found connected all round the urethral orifice in a line of perfect primary union, and the wound

[1] Quoted in Holmes's *Surgery*, second edition, vol. v, p. 181, by Professor Humphry, who, however proposes another mode of procedure, which suggested to me the idea of providing a covering of skin for the end of the stump in combination with Teale's plan.

over the end of the stump was likewise entirely healed except the part where the drainage-tube had lain. The same dressing was continued till this spot also had cicatrized, the blood-clot within the pouch of skin becoming organized without suppuration; and the patient left the hospital three weeks after the operation, having suffered literally no pain or inconvenience from first to last, and with a remarkably natural appearance of the part.

This case illustrates well, though on a small scale, the whole subject of this paper. Without antiseptic measures the careful fitting and close stitching of the parts would in all likelihood have been so much trouble thrown away. The wound at the end of the stump would probably in a few days have been freely opened up through suppuration due to putrefaction of the blood-clot in the investing pouch, and the stitches around the urethral orifice would soon have cut their way out under the influence of acrid ammoniacal urine. Again, even though putrefaction had been prevented, had the little drainage-tube been omitted and an additional stitch inserted in its place, tension from accumulated blood and serum would have arisen, producing inflammatory disturbance which might have marred the whole result. And, lastly, if an antiseptic more irritating to the skin or mucous membrane had been kept in contact with the wounds, it would, in proportion to the degree of its irritating property, have interfered with the primary union both at the new meatus urinarius and at the end of the organ.

It is with regard to this last point that the special value of boracic acid is exemplified. In such a situation it would have been practically impossible to maintain in position a protective layer such as is used under a dressing of carbolic acid; but, thanks to the mildness of the watery solution of boracic acid, the absence of such protective and the frequent copious ablutions with the antiseptic were productive of no disadvantage.

In further illustration of the value of the wet boracic lint for operations in this situation I may mention a case of aggravated hypospadias under my care last winter. The floor of the urethra was deficient from the end of the penis to about the middle of the scrotum, which in its cleft condition resembled at first sight the labia of a female; and for about three-quarters of an inch from the end of the glans the mucous membrane was entirely absent, a shallow sulcus lined with the integument being the only indication of the canal. The mode of procedure adopted was as follows: A straight rod, as large as a full-sized catheter, being held vertical by an assistant, with its extremity inserted in the orifice of the complete part of the urethra in the scrotum, the skin of the penis and front of the scrotum, by virtue of its extreme laxity, could be readily made to slip upon itself so as to cover in the straight bougie, meeting in two folds

in the middle line, and my object was to get the margins of these folds to unite by paring them and stitching them together, so as to complete the urethra with epidermis-covered skin on the internal as well as the external surface. But, as I knew that perfect absence of tension in the uniting parts would be essential to success, I freed the skin by three preliminary incisions, one in the middle line of the dorsum of the penis throughout its length except the preputial margin, and two in the anterior part of the scrotum, obliquely placed so as to be more or less parallel to the urethra at that situation. These incisions gaping widely permitted the cutaneous folds to meet with the utmost freedom in the situation of the proposed raphe, and their rounded margins being pared off, they were closely sewn together with deep sutures of silver wire and intermediate superficial ones of horsehair for accurate approximation of the external cutaneous edges, the wounds at the sites of the preliminary incisions being left to heal as they might.

As regards the antiseptic measures, the penis and scrotum were thoroughly washed with 1 to 20 carbolic lotion before the operation, which was performed throughout under the spray, as it was of essential importance to avoid the presence of any septic material in the blood-clots which might collect between the approximated raw surfaces or in the interior of the new urethra. Then with respect to the subsequent avoidance of the access of putrefaction, I knew that no contamination would come from within—that is to say, from the sound part of the urethra—because it had been abundantly established by experiments which I had made with reference to the germ theory of fermentative changes [1] that a perfectly healthy urethral mucous membrane is free to its extreme orifice from septic organisms. All that was needed, therefore, was an efficient external antiseptic dressing, mild enough in its action to permit healing to take place beneath it, for which purpose wet boracic lint was the most eligible. But there was this peculiarity in the present case, as compared with that of cancer of the penis above recorded, that the patient, being only six years old, could not be entrusted with the management of any part of the dressing on the occasions of micturition ; and even if a special nurse were provided for this charge, there would be great risk of negligence on her part letting in the septic mischief. This difficulty was got over by never allowing the parts to be exposed at all, either by nurse or patient, but keeping them permanently covered with a mass of moist boracic lint, securely fixed in position by stitching it to a T bandage, the ends of the split longitudinal part of which were not only attached to the part that encircled the pelvis, but were also carried round the upper parts of the thighs and crossed over the perineum. Over this permanent dressing was

[1] See 'A further Contribution to the Natural History of Bacteria', &c. (See vol. i, p. 309.)

applied an apron of wet boracic lint and gutta-percha tissue, fixed by an ordinary T bandage, which could be loosened at pleasure; and directions were given to the nurse that when the boy, whose hands were tied out of harm's way, wished to relieve the bladder she should loosen the outer bandage, and, raising the apron, allow him to pass his water through the mass of the permanent dressing into a bed-pan placed beneath him to receive the urine and also a copious effusion of saturated boracic solution which was to be poured on at the conclusion of the act; after which the apron was to be readjusted. This plan answered completely: there was nothing to indicate inflammatory disturbance; and when, after the lapse of about a fortnight, the stitches were removed, perfect union was found to have taken place along the middle line, except a small oval aperture about the base of the prepuce and a minute orifice, like a pin's point, at the scrotum, which now no longer suggested by its form the characters of the other sex. The retractile preputial covering of the glans was quite natural in appearance, except the oval aperture before mentioned, which will no doubt be readily closed at a future period; and the new canal, being formed of non-contractile material, is sure to remain of adequate calibre. The sores resulting from the incisions were at the same period far advanced in healing, and their cicatrization was soon completed under a continuance of the same mode of dressing.

There can be no doubt that the irritation caused by fermenting urine has hitherto been a great cause of failure in plastic operations in this situation; for which, therefore, we may fairly anticipate a far greater measure of success in the future.

While this paper has been going through the press, another case has occurred so illustrative of this department of the subject that it seems deserving of introduction. A boy nine years old being brought to me on account of difficulty of micturition, I found that though, on superficial inspection, the meatus urinarius appeared natural, it was merely represented by a shallow sulcus in the integument, except at the posterior extremity, where an orifice existed so minute as only to admit the eyed end of a fine sewing needle. It would have been an easy matter to have extended this aperture by cutting backwards; for the soft parts between the urethra and the surface were very thin at the ventral aspect of the organ, so that the edges of the divided skin and mucous membrane could have been readily brought together by sutures for primary union. But such a procedure would have resulted in an inferiorly situated meatus urinarius, or, in other words, a degree of hypospadias. On the other hand, to cut forwards through the substantial spongy texture of the glans seemed at first sight most unpromising, because it would be impossible to cover in the wound with skin

or mucous membrane, and the lateral granulating surfaces which must result would have a powerful tendency to coalescence at their angle of union in front. But on reflection I determined to try this latter method, in the hope that a more favourable issue might be obtained through avoiding as much as possible all irritation of the divided textures, by providing a smooth metallic surface for contact with them, and at the same time preventing the urine from becoming acrid through putrefaction. The operation was performed, on the 9th of March, by making successive notches forwards with a tenotomy knife guided by successively larger metallic rods till the incision extended through the whole length of the superficial sulcus which indicated the natural position of the meatus, and a No. 12 bougie could be passed freely into the canal. I then introduced and secured with a T bandage a gum-elastic catheter, of about No. 9 size, having its anterior end sheathed for an inch and a half or so with a tube of Berlin silver to serve the double purpose of presenting a smooth surface to the divided textures and conferring rigidity upon the portion of the flexible tube which occupied the terminal part of the canal and that which projected beyond it, so that it might be tied in with perfect security. The metallic portion was also expanded at a short distance from its free end into a collar presenting a concave surface towards the glans, to protect the new meatus from irritation by the threads used for tying in the instrument. The catheter was made long enough to reach back to the membranous part of the urethra, but not into the bladder, in order to allow the patient control over his urine ; and the eye was terminal instead of lateral, to admit of free exit for the fluid. The antiseptic arrangements were exactly as in the last case ; that is to say, I trusted to the ascertained physiological fact that the healthy urethra contains no fermentative organisms ; and, after scrupulously cleansing the external integument with 1 to 20 carbolic lotion, conducted the entire operation under the spray, and at its conclusion packed moist boracic lint around and over the organ, making it especially substantial in the perineum, where the urine would flow down ; and over this permanent dressing, which was fixed by stitches to the retaining bandage, was arranged a movable portion, in the form of an apron, of boracic lint, covered with thin macintosh ; a special nurse being provided to watch the boy, and attend to him during acts of micturition, as in the former case. The deep dressing was left untouched for five days, except that the patient passed his water through it, and that boracic lotion was poured freely over it after each occasion. When removed, it was found free from any ammoniacal odour, and a similar dressing was applied without disturbing the catheter. The second deep dressing was left untouched for another week, the boy meanwhile having lost entirely the pain in micturition of which he complained during

the first few days ; and when the lint was changed, after being soaked for seven days with urine, it was, like the first dressing, entirely free from ammoniacal smell. The catheter being now removed, the meatus presented the appearance of being completely cicatrized all round ; but at one spot the surface, though smooth, looked so delicate that I thought it prudent to apply one more dressing as before, to protect the tender part from the irritation of putrid urine. The catheter, however, was not reintroduced. Finally, on removing this last dressing five days later, I found the epithelial lining of the meatus obviously firm and sound throughout, and the orifice still freely admitted a No. 9 bougie. Thus, during the five days in which the newly made canal had been left unsupported, no contraction whatever appeared to have occurred—a result which seemed to be explicable by the healing having taken place, as it appeared, without the occurrence of granulation, so that the new tissue which had formed over the raw surface was in so thin a layer that the effect of its shrinking was insignificant.

Boracic acid may also be sometimes used with advantage in the form of an ointment, for which I would advise the following mode of preparation : Take of boracic acid, finely levigated, one part ; white wax, one part ; paraffin, two parts ; almond oil, two parts. Melt the wax and paraffin by heating them with the oil, and stir the mixture briskly along with the boracic-acid powder in a warm mortar till the mass thickens. Then set it aside to cool, after which it will be found to be a pretty firm solid mass, which is to be reduced to the proper consistence of a uniform ointment by rubbing down successive portions of about on ounce each in a cold mortar. This ointment, when used, is spread very thin upon fine muslin or linen rag, which absorbs more or less of the almond oil and leaves a layer of blended wax and paraffin, flexible at the temperature of the body, and separable from the skin with the utmost ease by the discharge, which is thus not at all confined by it, but diffuses itself and flows out beneath it, receiving as it goes an abundant supply of the acid to prevent putrefaction, while cicatrization is not materially interfered with by the mild antiseptic, and still less by the perfectly bland wax and paraffin.

A good example of the value of the boracic ointment was presented by a case of large rodent ulcer of the face lately under my care in the Edinburgh Infirmary, and treated by excision. The disease involving a large extent of the cheek, both eyelids, both nostrils, a considerable portion of the upper lip and part of the lower one, it was impossible to cover the raw surface by a plastic operation. It was therefore of great importance that efficient antiseptic means should be employed ; for there is no more simple or more striking illustration of the value of this principle of treatment than the entire absence of inflammatory

disturbance around an open wound when putrefaction is really prevented from taking place in it ; the ' stimulus of necessity ' of John Hunter being, in truth, simply the stimulus of putrefying substances, so that the danger which usually attends open wounds is entirely avoided by efficient antiseptic measures.[1] But whatever might be the material employed for this purpose, it was inadmissible to interpose a protective layer between it and the raw surface ; for this would simply have had the effect of conducting septic fermentation over the entire wound from the sources of putrefaction present at the mouth and nostrils. Seeing, then, that the antiseptic must be applied directly to the divided tissues, it was of course desirable that it should be as mild as possible consistently with its efficiency ; and for a situation like this the boracic ointment was much better adapted than the moist boracic lint, the fine cloth spread with it applying itself with facility and accuracy to the irregularities of the surface, and keeping its position without any retaining means except a packing of unprepared gauze applied over it to absorb discharge, and retained by a bandage of the same light material.

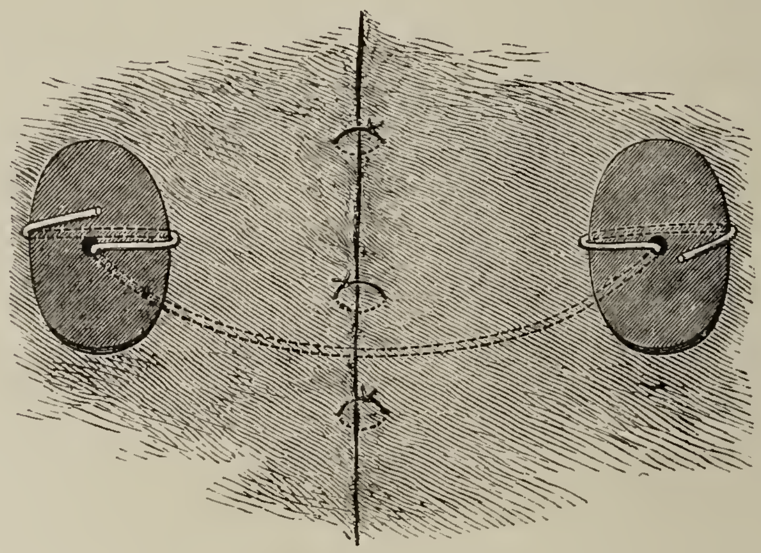
The eyeball, left bare by the operation, was protected from contact with the dressing by having the loose skin above the upper eyelid drawn down over it by means of the ' button suture ', as I may term a form of ' stitches of relaxation ',[2] which I have used for nearly two years with great advantage. It consists of two oval pieces of sheet lead, about one-twentieth of an inch thick, with a central perforation to receive a moderately thick silver wire. The silver wire is first passed as an ordinary suture, except that it is carried at an unusually great distance from the edge of the wound, both as regards surface and depth ; each end of the wire is then passed through the hole in the corresponding lead button, and secured by being wound once round the shorter diameter, as shown in the accompanying sketch (p. 242). The two buttons thus take the place of the tips of two fingers of the two hands in giving support to the deeper parts of the wound, while leaving the cutaneous margins entirely free ; and when the wound is at all extensive several pairs of buttons are applied in this way, constituting a sort of interrupted quilled suture. By their means the lips of a wound which otherwise could not be got to meet without considerable tension will often lie

[1] To this statement it is necessary to make an exception with regard to erysipelas, which I have known to appear in some surgical patients from whose wounds, as far as I was able to judge, all fermentative agency from without had been excluded. But, except during an epidemic of this disease, such as prevailed in Edinburgh about two years and a half ago along with a virulent outbreak of small-pox, the chance of its occurrence under strict antiseptic management is so small that it scarcely needs to be taken into consideration.

[2] The importance of special stitches of relaxation—' Entspannungs-Nähte '—was, so far as I am aware, first pointed out by Professor Simon, of Heidelberg, in his important work on vesico-vaginal fistula.

in contact of their own accord, any number of superficial sutures being added that may seem desirable to keep the edges of the skin in accurate apposition with a view to primary union.

The larger the surface which the buttons present to the skin the greater is their hold upon it, and the less, consequently, is their liability to glide and allow the wire to cut through the tissues by ulceration. When the circumstances of the wound allow them to be used as large as they are represented in the sketch, as after removal of the mamma, it will probably be found, when they are removed after the lapse of a week or ten days, that the buttons still occupy precisely the same situations that they were originally placed in, the surface beneath them being slightly depressed, but, in consequence of the diffusion of the pressure, not ulcerated, and this even in cases in which, a large amount of skin



having been sacrificed, they have been made to exercise a degree of traction which without experience would seem inadmissible. But much smaller buttons, though less perfect in their action, will often be found of great value in small wounds, as, for example, after the operation for hare-lip, where they take the place of strapping, but work much more effectually and also much more conveniently, as they leave the cutaneous margins free from compression and open for inspection. Here, indeed, at the upper part of the wound the small size of the buttons is attended with little disadvantage, because, being applied to the alae of the nose in planes nearly perpendicular to the direction of the wire, which perforates the tissue deeply below the septum narium, they cannot glide at all upon the surface, but, retaining their position perfectly, prevent in a very satisfactory manner the stretching of the uniting tissue at the nostril which is so prone to occur under strapping. In this particular situation, therefore, the only disadvantage of the necessarily small size of the buttons is that, their pressure being concentrated on comparatively small portions of the skin, they

will be liable to cause patches of superficial ulceration if the traction upon them should become increased by inflammatory turgescence. But if this threatens to occur, either in this particular wound or in any other, the difficulty is readily got over by unwinding the wire from one of the buttons, and, after straightening it, allowing the button to slip upon it to any degree to which the tension disposes it, and then fixing it again by winding the wire round it. And, conversely, if the support of the buttons is still required after they have become slack from any cause, they can be braced up at pleasure to any requisite degree.

Even when the edges of the wound cannot be made to meet at all, the extent of the exposed tissues and consequent granulating surface and cicatrix may be greatly reduced by the use of the button stitches, as was illustrated by the case of rodent ulcer which we are considering, where a single pair of buttons being applied, one to the skin above the eyelid and the other to that over the lower border of the jaw, the connecting wire lying exposed on the raw surface, the integument thus drawn down formed a permanent covering for the eyeball.

To return to the effect of the antiseptic dressing in this case. It was beautiful to witness the entire absence of inflammatory disturbance in this large open wound, involving such exquisitely sensitive parts, the surrounding skin remaining free from day to day from any inflammatory blush or puffiness, and the patient experiencing absolutely no uneasiness after the smarting[1] which immediately followed the operation had subsided, as it did within a few hours of its performance. On the changing of the dressing, which was done daily during the earlier periods, the entire mass came off like a mask, without adhering in the least to the wound, while there was no accumulation whatever of the discharge, which constantly passed freely out into the porous mass arranged to absorb it ; and there was never observed the faintest putrefactive odour. Cicatrization also proceeded satisfactorily from all parts of the edges of the wound, and it was an interesting circumstance that, while the epithelial ring which was thus formed had, in the greater part of its extent, the denseness and opacity of an ordinary scar upon the skin, the portions in the vicinity of the upper lip and nostrils had a peculiar delicacy and transparency, allowing redness of the subjacent vascular structures to show so distinctly that, except for their smoothness and dryness, these parts of the cicatrix might have been mistaken for unhealed granulating surface. The explanation obviously was that the epithelial formation, taking place only as the offspring of pre-existing epithelium, partook of the character of that from which it grew, having the density and

[1] This smarting was probably chiefly due to the effect of the solution of chloride of zinc, which, as an additional precaution, I had applied to the parts of the wound in the immediate vicinity of the mouth and nostrils.

opacity of epidermis when it sprang from the edges of the skin, but possessing the delicacy of the epithelium of the interior of the lip and nostril when, the skin of those parts having been all removed, cicatrization proceeded from the margin of the mucous membrane. Ultimately there was about one inch in breadth of the lower portion of the scar which presented these peculiar characters; and the mucous cicatrix would doubtless have been more extensive had I not supplied centres of epidermic growth over the general surface of the sore by skin-grafting.

The mode in which this was done deserves a moment's notice. As cicatrization was proceeding so satisfactorily under the boracic ointment, I thought this application might perhaps prove not inconsistent with the preservation of the vitality of skin grafts, so that the advantage of the procedure might be obtained without putrefaction occurring in the sore, as would be the case if the surface were covered with protective. I accordingly conducted the little operation in the manner that has been described in an earlier part of this paper, except that as each graft was laid down I placed upon it a morsel of the fine rag spread with the ointment, a general piece being afterwards applied over all to cover in the whole sore. But, to my disappointment, it turned out that not a single graft took. The ointment, though so mild in its action as not to prevent cell growth from epithelium which retained its connexions with its living neighbours, was yet too strong for the portions of epidermis which were weakened by isolation, and, before they had time to unite with the granulating surface, operated upon them as an irritant or as a caustic. I therefore repeated the process with this difference, that each graft, when placed upon the sore, was covered with a very small square of the oiled silk protective dipped in boracic lotion, and over this a rather larger square of the fine cloth spread with the ointment, a large piece being afterwards applied to cover the whole. Thus each graft was protected from the direct action of the boracic acid in the ointment, while the bits of protective were everywhere so overlapped by the antiseptic layer as to prevent putrefaction from entering. The result of this procedure was that every one of the numerous grafts adhered, and the healing of the sore proceeded to its completion with much greater rapidity, and I believe with much less contraction of the scar, than would otherwise have been the case.

In plastic operations such as those for the repair of the lower lip, the deeper edges of the wound communicating with the buccal cavity with its septic contents, any sort of antiseptic treatment may at first sight seem altogether out of place. But the primary union between the cut surfaces, which may be reckoned on almost as a matter of certainty if the operation has been so conducted that the edges of the wound can be brought together without tension, prevents the

spread of putrefactive fermentation outwards from the saliva and buccal mucus. For it would appear that the living tissues of the cut surfaces, provided that their vital energies are not impaired by inflammatory disturbance, operate upon a thin layer of blood or lymph (fibrine) between them in the same sort of way as the mucous membrane of a perfectly healthy urethra acts upon the mucus or residual urine contained in it, as before alluded to in connexion with the case of hypospadias: that is to say, the healthy living tissues prevent the development of septic organisms in their immediate vicinity; and this I believe to be the explanation of the possibility of primary union without antiseptic treatment. Thus the process of primary union is a sort of natural antiseptic arrangement so far as the materials between the cut surfaces are concerned; and hence it is quite reasonable to employ external antiseptic means after a plastic operation in such a situation. And, in point of fact, it will be found well worth while to apply a strip of fine rag spread with boracic ointment sufficiently broad to cover the lips of the wound and the points punctured by the sutures, retaining it in position by a somewhat broader strip of unprepared gauze, with its edges glued down with collodion. The result is that, the surface being kept moist and at the same time free from putrefaction, the occurrence of the troublesome pustules which are so often seen under scabs in the line of incision or about the stitches is prevented, and the union along the cutaneous margins, which it is so important to secure, is attained with much greater certainty and perfection. The ointment should not be applied till oozing of blood has ceased; and until this has occurred, the wound is kept covered with a piece of boracic lint.

I need hardly remark that to operate under the spray when the wound communicates with the septic buccal cavity would be an absurdity. The use of carbolic lotion should also be avoided, on account of the irritation which it occasions to the tissues. There is, however, no objection to having the sponges rendered pure by wringing them out of the mildly acting boracic lotion.

In operations of this kind silver wire for the deeper stitches and horsehair for the superficial ones answer extremely well; the rigidity of the wire enabling it to give valuable support, while both these kinds of material are mechanically antiseptic, since they afford no nidus for putrefactive fermentation in their substance, and both are so smooth in surface as to be in that respect quite unirritating. For microscopic examination of horsehair shows that its external epithelium, unlike the imbricated arrangement which prevails in many hairs, such as those of the mouse or of the human head, is so arranged as to produce perfect smoothness, a circumstance which is probably further valuable from the facility with which adhering dust can be removed.

One other use of the boracic ointment remains to be mentioned—namely, as a substitute for oiled silk protective in cases attended with inevitable putridity of the discharge from the interior of the part concerned; as, for example, after excision of a joint on account of caries attended with sinuses, where the injection of chloride-of-zinc solution has failed to eradicate the septic condition of the interior. Under such circumstances, though it is not possible to prevent putrefaction, it is very desirable to mitigate it, both for the sake of the part itself, and still more in order to avoid as much as possible the contamination of the atmosphere of the ward or sick chamber. But if oiled silk protective is applied beneath the antiseptic gauze, or dry boracic lint employed, the putrefaction present in the pus effused beneath it will continue to advance unchecked; and unless the dressing be changed daily, the oiled silk will acquire a very foul and irritating character. And even a dressing of wet boracic lint applied next the wound and covered with gutta-percha, though it answers the purpose much better, may become very putrid in the course of forty-eight hours, in consequence of the pus accumulating beneath it and so eluding the action of the acid. But if a piece of fine cloth spread with the boracic ointment is substituted for the protective, the discharge, compelled to diffuse itself in a thin layer beneath the ointment, continually receives from it a supply of the acid, which corrects more or less its original putrefaction; and the result is that after the lapse of two or even three days, the fetor is much less than it is in twenty-four hours under oiled silk protective or water dressing; and thus, while the atmosphere of the apartment is kept comparatively pure, the patient and the surgeon are saved the disadvantages of needlessly frequent dressing.

AN ADDRESS ON THE EFFECT OF THE ANTISEPTIC TREATMENT UPON THE GENERAL SALUBRITY OF SURGICAL HOSPITALS

Delivered in opening the Surgical Section of the British Medical Association in Edinburgh, August 4, 1875.

[*British Medical Journal*, 1875, vol. ii, p. 769.]

Gentlemen.—I believe I can hardly more profitably occupy the time allotted to me for an address in opening this section, than by bringing before you some facts illustrative of the effect of antiseptic treatment, when strictly carried out, upon the general salubrity of surgical hospitals.

Six years ago, when writing on the very remarkable improvement which had been brought about by 'enforcing strict attention to the antiseptic principle' in the wards of which I had charge in the Glasgow Royal Infirmary, 'converting them from some of the most unhealthy in the kingdom into models of healthiness,' I ventured to express myself thus: 'Considering the circumstances of those wards, it seems hardly too much to expect that the same beneficent change which passed over them will take place in all surgical hospitals, when the principle shall be similarly recognized and acted on by the profession generally.'[1] That prediction, I think I may say, is now in course of fulfilment.

I shall speak first of what has come to my knowledge with regard to some foreign hospitals, and I will begin with Copenhagen, where Professor Saxtorph long ago introduced antiseptic treatment; indeed, I believe he was the first to bring it into operation on the Continent. The large hospital of which he had the charge used to be a very unhealthy one. Pyaemia was extremely frequent, even after very small operations, such as amputation of a finger. Pyaemia has vanished ever since the antiseptic treatment was introduced, hospital gangrene has almost entirely disappeared, and erysipelas is nearly unknown except as imported from the town. Professor Saxtorph writes to me as follows: 'If you ask me what I have observed respecting the effects of antiseptic treatment, I may say that it has not modified, but completely changed my principles of pathology and my surgical practice. . . . The word *hospitalism*, which some years ago found its way from Edinburgh to the Continent, no longer terrifies us; it no longer keeps us from performing operations in the infirmary, and you seldom meet with a case that could be called a case of hospital disease.'

[1] See *Lancet*, January 8, 1870 (see p. 123 of this volume).

After going into details regarding the various forms of hospital disease, he proceeds to describe the greatly increased success that now attends the treatment of some injuries. 'As to accidental deep wounds, large lacerated wounds of the scalp, contused wounds with smashing of hand or foot, compound fractures or wounds of joints, I almost invariably have them heal without any bad symptoms, by means of antiseptic dressing and drainage-tubes. Any case of this sort will almost certainly recover if there is no complication of shock, or gangrene of the limb, or contusion of internal organs.' He next speaks of the change which has taken place in the results of operations, such as amputations and excisions, and adds, 'In short, I think I am right in saying that patients very seldom die from an operation. If they do die, it is not the operation that kills them, but the disease that existed previously to the performance of the operation.' Lastly, he alludes as follows to abscesses connected with diseased bone. 'What until the last few years proved the most difficult to deal with, are the abscesses which are connected with bone-disease. But now I think we may safely cut into them, if we only persevere in the antiseptic treatment for a sufficiently long time. By means of careful dressing, drainage-tubes, and the antiseptic spray whenever the dressing has to be changed, we get over those accidents of septicaemic poisoning which formerly almost invariably followed incision into these collections. But I am equally sure that, if I do not carry out the antiseptic treatment to its full extent, it is of no use whatever to apply carbolic acid to a wound, at least as regards the dangers that always accompany putrefaction.'

I come now to what I witnessed in the course of my recent travel in Germany, and I shall speak only of those hospitals into which antiseptic treatment has been introduced. Of these, the first I saw was Munich. The large Allgemeines Krankenhaus there has been until lately increasingly unhealthy; pyaemia was very frequent; and hospital gangrene, which made its appearance in the year 1872, had become annually a more and more frightful scourge, until last year it had reached the astounding proportion of 80 per cent. of all wounds that occurred in the hospital, whether accidental or inflicted by the surgeon. And not only was it thus extremely frequent, but was in a very severe form, produced frightful ravages, often caused death, and led to patients who recovered being retained an inordinately long time in the hospital. But, from the time when, at the beginning of the present year, efficient antiseptic treatment was brought into operation by Professor Nussbaum, they have not had one single case of hospital gangrene. At the time when I was at Munich, they were doubtful whether they had had one case of pyaemia; erysipelas, formerly very prevalent and severe, was rare, and, when it did occur, was in a very mild form; and

I saw the convalescent wards—which previously had always been filled and overflowing—standing one after another empty, because the patients, no longer affected with hospital gangrene, recovered much more rapidly.[1]

I next proceeded to Leipzig, where Professor Thiersch is clinical teacher. He has three hundred beds under his own charge, of course seconded by able assistants. Professor Thiersch was the first to introduce antiseptic treatment on scientific principles into Germany. His results, as regards the general salubrity of the hospital, have been, on the whole, progressively more and more satisfactory, and in the present year he was able to state that he had only had one case of pyaemia in twelve months ; and that, you will observe, in a service of three hundred beds. Hospital gangrene, also, had almost disappeared. There had been in 1871 a curious attack of that disease in two barrack wards, which seemed to be due to old hospital furniture piled up in an empty space under those apartments ; but of late this also has vanished. Professor Thiersch has of late used, instead of carbolic acid, salicylic acid as an external dressing ; but he still employs carbolic acid for the spray and lotion. Salicylic acid, as he uses it, certainly works very well ; but that his increasingly satisfactory results are due to any special virtues of that agent cannot be maintained.[2]

From Leipzig I passed to Halle, where I found Professor Volkmann carrying

[1] Since the delivery of this address, I have received from Professor Nussbaum a pamphlet entitled *Die Chirurgische Clinik zu München im Jahr* 1875 : Ein Andenken für seine Schüler. Published by Ferdinand Enke, Stuttgart. The subject of this work is the complete revolution brought about in the salubrity of the hospital by antiseptic treatment, and the means by which this result has been attained. One passage from the first chapter seems to me to demand reproduction here. After describing the previous frightful state of unhealthiness, he says : 'Everything that we had tried against the above-mentioned horrors had proved unsuccessful. The open treatment, the occlusion dressing, the continuous water-bath, irrigation with chlorine water or with carbolic-acid solutions, salicylic acid in powder and in solution, the putting on of Lister's antiseptic materials—carbolic paste, &c.—all, all were unable to combat hospital gangrene and pyaemia. But when in the course of a single week, with great energy and industry, we applied to all our patients the newest antiseptic method, now in many respects improved by Lister, and did all operations according to his directions, we experienced one surprise after another. Everything went well ; not a single other case of hospital gangrene occurred. Pyaemia and erysipelas were observed a few times at the very beginning ; but only, as the result proved, because we did not yet possess the necessary practice in the carrying out of Lister's directions. We took pains, as you know, and learned from day to day more exactly how to comply with his instructions. Our results became better and better, the time of healing shorter, and pyaemia and erysipelas completely disappeared' (op. cit., p. 6).

[2] The true explanation of the improved results is given by Professor Thiersch himself in the following passage in a work which he has recently published on this subject—a statement characterized by the usual perfect candour of the distinguished writer : 'Our results have constantly improved in proportion to the perfecting of the method and our own practice in carrying out its details. They are, indeed, not so good as those of Lister himself, or of Volkmann, &c.' (see *Klinische Ergebnisse der Lister'schen Wundbehandlung*, &c., one of the *Klinische Vorträge* edited by Volkmann ; Leipzig, 1875, p. 645). To the same cause, I have little doubt, is to be attributed the fact that erysipelas was considerably less ('bedeutend geringer,' op. cit., p. 676) in the year 1874 than in the previous year. Professor Thiersch himself believes that erysipelas is not influenced by antiseptic treatment; but this view is entirely opposed to the experience of Saxtorph and Nussbaum already mentioned in the text, and to that of others to be alluded to in the sequel.

out antiseptic treatment just in the same way as we do here. He gave an antiseptic demonstration, to which he invited professors from various parts of Germany; and he certainly showed us a magnificent set of cases. It was, I confess, somewhat gratifying to me that Professor Volkmann had obtained his results without any of his assistants having visited Edinburgh. Seeing the importance of the subject, he had worked in good earnest at the system, in accordance with what he had read of my writings. He told me he had only gradually got into the way of carrying out the system properly; but I had the satisfaction of seeing everything done exactly as we do here, and with results of the most brilliant kind. That hospital was previously an extremely unhealthy one. The wards are small and overcrowded; each one has a water-closet opening into it, and a large drain of the city runs under the wards. Indeed, the building is so confessedly bad, that it has been condemned to demolition. Pyaemia used to be exceedingly common there; but, since the introduction of antiseptic treatment, a change has taken place which I can best describe by a quotation from a paper by Professor Volkmann himself[1]:—

'I had hoped to have been able to publish before now the communication which I made on the antiseptic treatment and Lister's mode of dressing, on the occasion of the third Congress der deutschen Gesellschaft für Chirurgie; but as this has, unfortunately, not been the case, I may, perhaps, be allowed to mention here a few facts for the purpose of showing how greatly the danger of some forms of injury, which were formerly followed by a very high rate of mortality, is diminished by this procedure.

'Since the introduction of the antiseptic method into my *clinique*, now exactly two years ago (at the end of November 1872), no single patient suffering from a compound fracture, in which conservative treatment was attempted, has died. Amongst this number are included even those cases in which conservative treatment was only resorted to because the patients would not give their consent to amputation, and also those in which we at first underestimated the severity of the injury, and afterwards intermediate or secondary amputation had to be undertaken on account of haemorrhage or gangrene. The number of compound fractures successfully treated without a single fatal result in our hospital, which is old and always overcrowded, and offers the most unhealthy hygienic conditions, amounts at present to thirty-one. Amongst these were as many as nineteen compound fractures of the leg, in several instances much comminuted, and often complicated with most severe bruising and laceration of soft parts. There were also two compound comminuted fractures of the patella, both of which recovered with movable joints. No case of pyaemia has occurred for a year and a half—i.e. since July 1873—although during this period alone about sixty major amputations have taken place.'

I also learn that hospital gangrene is now entirely unknown in that hospital. Erysipelas likewise is extremely rare; and, where it does appear, it is of a

[1] See Professor Volkmann on Antiseptic Osteotomy, translation in *Edinburgh Medical Journal*, March 1875.

superficial and mild type ; and Professor Volkmann told me that his experience of the effects of antiseptic treatment in diminishing the amount and severity of that disease was so striking, that he entirely differed from the opinion of Professor Thiersch on this matter.[1]

Amongst the cases brought before us in Professor Volkmann's demonstration was one of excision of the hip-joint, where putrid sinuses had existed before the operation. About a week had passed since the operative procedure, but there was no purulent discharge whatever ; and no fluid even of a serous character could be pressed out from the small spot that alone remained unhealed, and the use of a drainage-tube had been already given up. In short, the case had followed the typical course we expect under antiseptic treatment when we operate with an unbroken skin. This is a kind of result I myself had never yet obtained, and it filled me with astonishment. I inquired how it had been arrived at, and I found it was as follows. Professor Volkmann several years ago strongly advocated the application to diseased soft parts of 'the sharp spoon' which had been introduced into German surgery by Bruns, of Tübingen, for scraping carious bone. Thus, supposing a strumous abscess to be opened, instead of leaving the degenerated textures around to come away by a tedious process of suppuration, or to be removed by slow absorption, he scraped it all out at once with the sharp spoon, and thus greatly accelerated the recovery. Being thus accustomed to the use of this instrument, he applied it to clear out the pyogenic membrane of putrid abscesses and sinuses, and all granulations around the diseased bones after excision. For my part, I have always, after operating upon such a case, treated the cut surfaces with solution of chloride of zinc, and injected the sinuses with the same, in the faint hope of exterminating existing putrefaction ; but I have practically never succeeded. The failure was always readily intelligible to me, on the ground that I could never get the antiseptic to penetrate all the recesses of the sinuses and the lymph or sloughs lying among the granulations. But here Professor Volkmann had cleared out the offending substances altogether, and then introduced an antiseptic lotion ; and he told me, to my amazement, that it was the rule with him to attain results of the character I then witnessed. If my journey on the Continent had been one of unmixed labour, I should have thought that labour well rewarded by this circumstance in my visit to Halle. I have already put this plan in operation in my own practice since my return, and I hope to show you some of the results to-morrow, at a demonstration in the operating-theatre of the Royal Infirmary. Whether I can obtain such frequent success as Professor Volkmann, I do not know ; but I have already succeeded in some cases.

[1] See note at the foot of page 249.

In Berlin, Professor Bardeleben, with one hundred beds under his care at the Charité Hospital, has long introduced the antiseptic system. The hospital used to be a very unhealthy one. Pyaemia was so frequent, that amputation in the lower limb was almost certain death to the patient ; but, through antiseptic treatment, this has for a long time past been entirely changed. Professor Bardeleben informed me, at the time of the meeting of this Association in London, that pyaemia was practically abolished from the wards, without any other change than the introduction of antiseptic treatment ; and I found that this same satisfactory condition of things continued at the time of my visit this year. Erysipelas was also rare, and of a mild type ; and hospital gangrene very uncommon. At the same time, I feel bound to express my conviction that Professor Bardeleben would get still better results had he not been led, on the score of economy, to substitute for our antiseptic gauze unprepared gauze soaked with a watery solution of carbolic acid ; for here, the carbolic acid being dissolved in a liquid, instead of being stored up in an insoluble medium, the antiseptic and its vehicle are both displaced together by the discharge which soaks into the dressing, and this involves great additional risk. In fact, Professor Bardeleben told me that for very special cases he still used our antiseptic gauze.

In the other great clinical hospital of Berlin, the renowned and veteran surgeon Von Langenbeck had not until the present year seen his way to adopting antiseptic treatment. He had professed admiration of various results he had heard of ; but, as Professor Bardeleben said, it had been barren admiration. But it was a singular coincidence, and one very gratifying to me, that, when I called upon him, I found him preparing to perform his first operation according to strict antiseptic principles. The case was one of tumour of the upper end of the fibula ; and, considering the possibility of the wound communicating with the knee-joint, he felt himself bound to use antiseptic treatment. This he did with perfect faithfulness, in spite of the serious inconvenience of a most unnecessarily wetting spray ; and, when the operation was concluded, he did me the honour to ask me to put on the dressing.

At Magdeburg, I found a great hospital, containing, on the average, one hundred surgical patients. This hospital used to be noted for its unhealthiness ; but I learned that, since the introduction of antiseptic treatment, an entire change had come over it in this respect. Pyaemia has almost entirely disappeared, hospital gangrene has gone, and erysipelas, when it occurs, is of a very mild type.[1]

[1] Dr. Hagedorn, the chief surgeon, was absent at the time of my visit ; but in a letter, which, through accidental circumstances, I did not receive till after this address was delivered, he describes in full detail the change that antiseptic treatment has effected. From this letter I must content myself with quoting two short passages. 'I have now been for twelve years chief surgeon to the hospital

At Bonn, also, I heard similar testimony. I learned from Professor von Busch, who introduced antiseptic treatment into the clinical hospital last year, that some previously unhealthy wards had since quite changed their character; and that in some fine airy wards, which were always very free from hospital disease, the mode of healing of the wounds was something altogether different from what it used to be.

So much, then, gentlemen, for my continental experience. And now I wish to say a few words as regards the infirmary here, where I have now been at work for about six years. And, first, as to the conditions under which I am working. The wards, as some of you have seen, are small and overcrowded. These wards were never so severely tested as they have been since I came here. There used to be, in the old High School building, two reserved wards kept ready for the reception of erysipelas or other peculiar cases; but, at the time when I was appointed, twenty beds were taken off from the clinical surgical department for the purpose of creating a new surgeoncy; and, at the same time, the two reserved wards previously kept empty were filled with patients. That particular block of building has, therefore, been more severely tried than ever it was before. The number of beds is so limited that there is always great pressure upon them. When I came to Edinburgh from Glasgow, seeing the beds so close, I had several of them cleared out; but the result was, I found, that the same number of patients were admitted; and there always being a considerable proportion who could walk about during the day, they were put down on mattresses on the floor at night, so that the number of patients remained as before; and, as the wards continued perfectly healthy, I had the beds reintroduced. But, more than this, I have still the mattresses on the floor. If you were to go into these wards sometimes at night, you would be surprised to see how many 'shake-downs' there are. We have, also, often two or three children in one bed; and altogether by these means, while I have fifty-five beds, I have lately had seventy-one patients. During the time I have been here, there has hardly been a day on which there have been as few patients as beds, although any of you can see that those beds are not as distant from each other as they ought to be, according to modern notions of what is requisite for the salubrity of a hospital.

Then there is another important respect in which my wards have been

and I had to do battle on a large scale with pyaemia and septicaemia, till in May 1872 I introduced your antiseptic method.' 'Since that time we have constantly practised it with excellent results, which, in truth, have been constantly improving; for at first the procedure does not always succeed, and every man must pay for his schooling (muss Lehrgeld geben). Now I have arrived at the conviction that your procedure is unconditionally secure, and that in every failure the surgeon himself is to blame, and not the method.'

more severely tried than before. There had previously always been an annual cleaning of the wards of our infirmary. Now, this involves considerable inconvenience. The patients had to be transported to another part of the hospital, and some cases were liable to be injured by this transport. Therefore, when the annual cleaning came about, I used to consider whether the patient would get more harm from the want of the cleaning of the wards, or from the transportation. I thought they were more likely to get harm from the transport; and this being year after year my conviction, it is now three years since any cleaning took place in these wards of mine. The year 1872 was the last in which it was practised, except in the case of one individual ward where a sore throat prevailed last summer, which seemed to be of the nature of scarlatina, and on that account the ward was emptied and purified. I have sometimes observed remarks made with regard to the results of treatment in my wards, to the effect that I work under superior hygienic conditions. It is, in truth, exactly the opposite. My wards, in these respects, are more severely tried, I believe, than those of any other surgeon in the kingdom.

Then it is said that greater cleanliness is involved in the antiseptic treatment. This, again, is an entire mistake. If we take cleanliness in any other sense than antiseptic cleanliness, my patients have the dirtiest wounds and sores in the world. I often keep on the dressings for a week at a time, during which the discharges accumulate and undergo chemical alteration, probably from oxidation and the action of the resin of the gauze upon them; and, when the wounds are exposed after such an interval, the altered blood with its various shades of colour conveys often both to the eye and to the nose an idea of anything rather than cleanliness. Aesthetically they are dirty, though surgically clean.

There is yet another way in which my wards have been unusually tried—namely that I now perform operations which, without antiseptic means, I should not have considered justifiable, some of them being of a character which used to involve especially the risk of pyaemia, such as cutting down on ununited fractures of the femur, and removal of the ends of the fragments.

Yet, in these circumstances, if I have had one case of pyaemia where I have operated myself, it is the only one I know of; and that was a spurious form of the disease. It occurred in a patient from whom I had removed the mamma, and, at the same time, cleared out all the axillary glands; and putrefaction took place in the axilla, in consequence, as we had reason to believe, of mismanagement of the spray. Of hospital gangrene we have not had one single case during these six years. As regards erysipelas, our experience has been various. As a rule, it is very rare in my wards. I have been two entire years

without a single case of it; but, on the other hand, there was a time when it was frequent. This was during a concurrent epidemic of small-pox and erysipelas in Edinburgh two years ago. The erysipelas was of a very virulent type, and some patients in private practice in the city died of erysipelas affecting the puncture of revaccination. At this time we had several cases of erysipelas admitted into my wards from the town, and several, also, took origin within the hospital. But the constitutional rather than the local cause of these cases was shown in several instances by the disease occurring not in or near the wound, but at some remote part, as in the head after an operation upon the penis. And it was somewhat remarkable that in no case did the disease as it originated in the hospital assume the malignant form which it sometimes exhibited in private practice.

Tetanus also appears to be rendered much less frequent by antiseptic treatment. Far be it from me to say that putrefaction is the only cause of it; we all know it is otherwise; but when I say that, in six years, with an average of sixty severe surgical cases, I have only had two cases of the disease, and those both of them in connexion with septic wounds, I show strong grounds for believing that, if we exclude putrefaction, we exclude one—and the most common—exciting cause of tetanus.

One objection that has been urged against my treatment is the inordinate length of time patients remain in hospital. No doubt it is so in some cases; but, as a rule, these are instances in which we expect to cure otherwise incurable cases, such as spinal abscess. But, on the other hand, on comparing Mr. Syme's case-books with my own, during two periods of three years, the unexpected result has lately been arrived at that, in proportion to my number of beds, I have had a larger number of operations than Mr. Syme; showing that, while some patients, kept alive by antiseptic treatment, have remained long in the hospital, this was more than counterbalanced by the rapid cure of others.

I trust, gentlemen, that the facts which I have now had the honour to bring before you will be considered pretty strong proof of the value of strict antiseptic treatment in promoting the general salubrity of surgical hospitals.

DEMONSTRATIONS OF ANTISEPTIC SURGERY BEFORE MEMBERS OF THE BRITISH MEDICAL ASSOCIATION

[*Edinburgh Medical Journal*, vol. xxi, 1875–6, pp. 193, 481.]

Demonstration I

Gentlemen.—I propose this morning and to-morrow morning to avail myself of such opportunities as happen to be at my disposal to illustrate before the British Medical Association the methods and the value of antiseptic treatment. The first case which I shall bring before you will show this treatment in its simplest form, and in one of its most striking instances—a case in which I propose to lay open the knee-joint. The patient (a man fifty-four years of age) was under my care some years ago, with a very large effusion under the deltoid, in an acute form, attended with much fever. I opened it antiseptically, and the patient made a rapid recovery without suppuration. He has thus already had experience of the value of antiseptic treatment, and therefore trusts it implicitly for the management of what he at present suffers from, namely, painful effusion into the knee-joint. It is of twelve months' duration, and has resisted repeated blistering (about a dozen have been applied in all), and from the peculiar prominence that exists over parts of the articulation, I suspect suppuration is imminent. Now, if blistering failed in a case of this kind, without antiseptic management the surgeon would be at a loss what to do. Dieulafoy's aspirator might sometimes prove serviceable, but those who have tried it must confess that they are often disappointed in consequence of the fine tube becoming blocked by portions of lymph. But by antiseptic means we are able to obtain, by incision and drainage-tube, a perfectly free exit for the fluid, and thus relieving the joint altogether from the tension due to effusion, permit the natural tendency to recovery to come into operation. I need hardly remark, that to do this without antiseptic treatment would be madness—would be a thing which no surgeon would be justified in doing; to make a free incision into the knee-joint and to keep the wound open with a drainage-tube, would be an altogether unwarrantable procedure. We all know that the knee-joint has often been opened by free incision for the extraction of loose cartilages, and that in some such cases, the wound having healed by first intention, all has gone on well without any antiseptic treatment at all; though we know also that this

is a very uncertain and dangerous practice. But though it is true that wounds of joints, whether accidental or intentional, may heal without disturbance under ordinary treatment, yet it is certain, that if such wounds were kept open without antiseptic means, disastrous consequences would be inevitable ; by keeping the wound open we should take away the only chance there would be, without antiseptic treatment, of the case ending without disaster. But, Gentlemen, paradoxical as it may at first appear, with antiseptic treatment the more free the wound, and the more widely it gapes, the more certain you are to avoid inflammatory disturbance in the joint ; simply for this reason, that you are the more certain of a free discharge of the plasma effused into the interior. And if you avoid all tension from this cause, and at the same time exclude putrefactive mischief, you have the joint left absolutely free from irritation. Before we bring the patient in, I may say that I shall make the incision pretty free as regards the skin, and carry it gradually down to the joint, so as to be able to see and secure any small artery that may be divided. For if you simply plunge the knife into the joint, and put in a drainage-tube, bleeding may take place into the articulation from some deep vessel, and lead to considerable inconvenience. Just as in Professor Andrew Buchanan's well-known experiment, hydrocele fluid is made to coagulate by the addition of a little serum from a blood-clot, so if a very little blood finds its way into the knee-joint, the liquor sanguinis effused from the synovial surface mixing with the globulin of the red corpuscles forms a coagulable fluid and undergoes coagulation, and you have the knee-joint filled with solid matter, which interferes with the rapidity of recovery, although in due time the accumulation disappears by absorption.

[The patient being now brought in, Mr. Lister proceeded]—Here, then, we have before us the distended knee-joint. You observe this peculiar limited special bulging, which, together with the history, makes me suspect that the joint is on the eve of suppuration.

I have said that this case will be an example of the antiseptic treatment in its simplest form. The antiseptic will not be introduced into the joint ; it will not be applied to the affected part at all. It will be merely employed externally to prevent the access of septic mischief while we provide exit for fluid from the interior. We shall first purify the skin with a strong (1 to 20) watery solution of carbolic acid, which is best for detergent purposes ; water holding carbolic acid but slightly, and very readily giving it up to act upon anything else. Carbolic acid has a remarkable penetrating property. It blends with oily substances and animal matters, and penetrates the hair and hair-follicles, and therefore such a washing as I am now giving will render the skin absolutely pure, surgically speaking. This is a very great point.

In the next place, we shall have an antiseptic atmosphere provided by means of this spray-producer, which acts on the principle of Siegle's steam inhaler. High-pressure steam, issuing by a minute orifice from a boiler heated by spirit-lamp or gas, sucks up a strong solution of carbolic acid by a tube that dips into a vessel containing it, and, blending with it in about equal quantity, forms a 1 to 40 spray. We have lately very much improved our spray by a slight alteration of the apparatus. We used to have the tube which conveys the carbolic solution perpendicular to that for the steam, just as the air-tube is at right angles with the water-tube in the common atmospheric odorator; and the result was a coarse spray with scattering drops, consuming a needless quantity of the solution, and causing needless irritation of the surgeon's hands and wetting of his sleeves; and, what was of more moment, inducing unnecessary irritation of the wound, and making around the trustworthy spray an area of uncertain extent completely valueless, because the solution in it was in the form of comparatively large drops with intervals of unaltered air. But, by placing the tube for the solution at an angle of 45° with that for the steam, and with its point ground off obliquely so as to be exactly in the axis of the steam-tube, we get a spray destitute of scattering drops, perfectly trustworthy throughout its visible extent, though little coarser than a London fog.

The slate on which I am now directing the spray is in an antiseptic atmosphere; yet so fine is the spray, that it scarcely moistens the surface. The face of one of my dressers is now enveloped by the cloud, which, as you observe, is capable of being inhaled without serious inconvenience. That we should be able to provide a respirable, yet reliably antiseptic atmosphere, is what I confess I never anticipated. The boiler has a safety-valve to prevent explosion, and a window to enable you to see when the water is becoming exhausted. A large spray-producer like this will go on working, with one supply of water in the boiler, for a couple of hours.

The part to be operated upon, then, being in an antiseptic atmosphere, if the finger is to be introduced into the wound (and I shall very likely have to pass my finger into the joint) you must take special care that it is an aseptic finger; and this is done by cleansing it with an antiseptic solution, making sure that it passes well into the folds of skin about the nail. And if I should have to introduce an instrument into the articulation, I must see that it is always pure when inserted. In order, Gentlemen, that you may get satisfactory results with this sort of treatment, you must be able to see with your mental eye the septic ferments as distinctly as we see flies or other insects with the corporeal eye. If you can really see them in this distinct way with your intellectual eye, you can be properly on your guard against them; if you do not so see them,

you will be constantly liable to relax in your precautions. I have seen, for instance, a gentleman, anxious to carry out the antiseptic treatment completely, take out a large loose cartilage from the knee-joint under the spray, using at the outset instruments which had been purified by lying in a solution of carbolic acid ; but in the course of the operation, I observed him take a pair of forceps which seemed better adapted for his purpose than any which he had so prepared, and simply dip them for an instant into the antiseptic lotion, and then plunge them into the interior of the joint. Now, Gentlemen, was that doing the treatment justice ? Between the teeth of those forceps there were probably portions of dirt. Give the carbolic acid lotion time, and it would penetrate this dirt, greasy though it might be ; but it cannot do so in a moment ; and nothing was more likely than that some portion of this dirt would come off from the forceps and remain in the joint, and induce putrefaction there. I have known of a gentleman with every anxiety to carry out antiseptic treatment, exploring the wound in a case of fracture of the skull, and, the probe happening to fall to the ground, it was taken up from the dusty floor, and immediately passed into the depths of the wound. Now, Gentlemen, that was but courting failure. What more likely than that some of the septic dust, which certainly was brought up adhering to the bloody probe, should pass into the wound without having been sufficiently acted on by the spray in the moment of transit, and, mingling with the blood in the interior, be there protected for the future by the blood-clots from the antiseptic influence of the dressings, and induce putrefaction ? If we could see the septic material upon the instrument as distinctly as we could see green paint in contrast with the red blood, then of course we should say, We must wash off this green poison ; but because we cannot see it with the physical eye, we are always liable to make mistakes through neglect of using proper precautions ; and I am more and more persuaded, the longer I practise antiseptic surgery, that the chief essential to success is a thorough conviction of the reality of the presence of the septic matter on all objects in the world around us. Through the kindness of the President of the Physiological Section, I hope to have the opportunity of demonstrating some facts which I believe will tend to convince you that the septic ferments are, like those of the alcoholic fermentation, living organisms—that they are analogous to the yeast plant. But whether you believe or do not believe that they are living, it is as certainly demonstrated scientifically as it is certain we are here, that these ferments do exist. If we do not bear that in lively remembrance, we shall be constantly making mistakes.

[Mr. Lister then proceeded to perform the operation. Some small arteries, which bled in the incision, were secured with fine prepared catgut, and the

joint having been opened, two drainage-tubes, each about $\frac{1}{4}$-inch in diameter, were inserted side by side ; an obstructing band within the articulation being divided by a probe-pointed knife guided by the finger so as to permit them to be introduced fairly into the cavity. He commented on the various steps as he proceeded, urging again the absolute necessity of having all the instruments thoroughly aseptic, and went on to say]—One learns after a while to do these little purifications instinctively, but at first it requires thought, intelligence, and constant care, particularly to any one who has been in the habit of operating without having to attend to these minutiae. Would that we could get rid of all complications in the system ! If we could dispense with the spray, no one would rejoice more than myself ; but until somebody wiser than I am can supply some better means, we must continue to use it. There is, I find, considerable thickening of the textures in the vicinity of the joint, and this is the cause of the swelling which is still apparent, though the synovial capsule is now empty. The outer orifices of the drainage-tubes are made transverse or oblique, as required, in order that they may lie flush with the surface of the skin, and when retained in this position by means of the threads which you see attached to their margins, they discharge their functions perfectly.

The operation having now been performed, the next point is so to dress the wound as to make sure that nothing septic will get in before next dressing ; this must be not a matter of hope but of certainty. The material which we have used for some time past is an open cotton cloth, with the fibres impregnated with a mixture of carbolic acid and common resin.[1] Common resin holds carbolic acid with extreme tenacity, and in consequence of this gives it off so slowly as to be unirritating to the skin ; yet at the temperature of the human body it furnishes a sufficient supply of the acid for a trustworthy antiseptic dressing. But at the ordinary temperature of the air in this country, the antiseptic is evolved so slowly from the gauze that the fermentative energy of septic dust is not at once extinguished by falling upon it, as it is by mingling with a strong watery solution ; and if the gauze were applied dry, some active septic particle adhering to its surface might enter the blood or serum at the outlet of the wound, and propagate putrefaction to the interior. There was a time when I used to have occasionally in my practice putrefaction which I could not explain, but which I afterwards saw must be due to this cause, and the difficulty was then at once overcome by dipping the lowest piece of gauze in a watery solution of carbolic acid. This solution which I am now using, having been mixed with blood from the wound, has a very dirty appearance. A surgeon, who went

[1] For details regarding the composition and mode of preparation of the antiseptic gauze, see *Lancet*, March 13, 1875 (p. 210 of this volume).

round my wards some time since, expressed astonishment that I should use dirty lotion to wash a wound, and to purify what I was placing upon it; but, Gentlemen, the wound, although aesthetically dirty, was surgically pure, and the lotion had not been made impure by being used for washing it. Even if it had been otherwise, we might have trusted the carbolic acid to purify it. Why then should we waste good lotion? I dip, therefore, in the lotion this piece of gauze that I place next to the wound, and thus make perfectly sure that nothing septic is applied to it.

It is most important that the spray be properly directed during the dressing. I have seen a surgeon expose a serious wound, involving injury to the brain, while the spray was only playing on the opposite side of the head. It were far better that the antiseptic method should not be employed at all than that it should be used imperfectly. For such attempts not only end in disappointment, but throw discredit on the system. Some people seem to say, 'I have tried the thing and failed, and therefore, of course, the system is all nonsense.' I have seen it fail in my own practice, but under such circumstances I have always thought there must have been some mistake on my part, and I have endeavoured to discover where my mistake lay. But that does not seem to be the way in which the matter is viewed by some of our professional brethren.

A small piece of gauze dipped in the lotion having been placed next the wound, the dressing on which we rely for excluding putrefaction is applied in the form of eight layers of the gauze, sufficiently broad, as you see, to cover the surrounding skin for several inches in every direction; and beneath the outermost layer is placed this piece of thin macintosh cloth to prevent the discharge from going directly through the dressing; because, if a considerable quantity went through, strongly as the resin holds carbolic acid, it might be all washed out before twenty-four hours had elapsed, and then putrefaction would spread inwards to the wound. The dressing is secured by a bandage, for which strips of the antiseptic gauze prove very convenient. Now, Gentlemen, we are perfectly sure that, if we have left nothing septic in the wound, we shall find no putrefaction when the dressing is changed to-morrow.

[The subsequent progress of this case has illustrated well the remarks made at the demonstration, with regard to the effects of a free opening, or the contrary, under antiseptic management. When I saw the patient on the following day, I learned that he suffered unusual pain in the afternoon after the operation, which became very severe during the night, and though somewhat less in degree at the time of my visit, was still very considerable. The temperature had risen on the previous evening to 102·4° Fahr., and was now 101·8°. Such a state of things would at one time have alarmed me, and would have made

me fear that putrefaction had occurred. This, however, I felt confident could not have been the case, and another probable explanation suggested itself. The peculiar bulging above alluded to, situated over one of the pouches of the synovial capsule beside the ligamentum patellae, had tempted me to make the opening in that situation ; but the bulging part collapsing on escape of the fluid, the only way in which I could ensure complete introduction of the drainage-tubes into the joint was by passing their ends under the ligamentum patellae ; and I thought it not unlikely that they might have been compressed, and their function so interfered with. Accordingly, on changing the dressing, I found that the gauze presented a bloody stain, which appeared sufficiently accounted for by oozing from the surface of the wound, while the joint was fully distended. And it appeared that the disturbance to which the articulation had been subjected had led to unusually rapid effusion from the synovial surface, and this being unable to escape, had produced great tension, attended with pain and fever. I at once placed him under chloroform, and made a fresh incision at the outer side of the limb into the pouch above the patella, and introduced a drainage-tube larger in diameter than the little finger, after pressing out the clear serous and fibrinous contents of the capsule. This was of course done with antiseptic precautions, and a dressing like that employed the day before was applied. The result was that almost immediately after awaking from the chloroform sleep, he felt himself entirely relieved of his pain ; and not only has that which was induced by the first operation left him, but he has entirely lost that which had annoyed him for so long a period previously. The temperature in the evening was found to have fallen to 99° Fahr., and has since remained normal, and the discharge, which has continued to be merely serous, has so diminished in quantity, that when I last saw him (August 15) I substituted a drainage-tube of medium size for the large one, and was able to direct that an interval of three days should be allowed to pass before the next dressing. I must add that he has tested the limb, contrary to orders, by getting out of bed and resting his weight upon it, but without any of the pain which he formerly experienced on so doing. In all other respects he is in perfect health.

It happens, by a curious coincidence, that another patient requiring the same operation has since been admitted under my care in the infirmary ; a man twenty-six years of age, who, six days before admission, observed a painful swelling in the left knee, without assignable cause, and both pain and swelling had since steadily increased. The skin, however, was free from redness, and, subacute as the case was, I hoped that entire rest, with efficient fomentation, would relieve him. On the contrary, pain continued to increase during the next five days, while the temperature rose above 100° Fahr. ; and on the 11th

inst. I introduced a large-sized drainage-tube into the joint by incision above the patella, at the outer side of the limb. With the serous fluid that escaped were mixed considerable portions of lymph, opaque, and in some parts of yellowish-white colour ; and these portions proved on microscopic examination to be masses of pus corpuscles ; so that it was clear that the case was just passing into one of that justly dreaded disease under ordinary treatment, suppurative synovitis. The result, as in the former case, was immediate and permanent relief from pain. His temperature next day was normal, and has remained so. The discharge, purely serous in quality, is quickly diminishing in quantity, and the patient eats and sleeps as in perfect health.]

The next patient I wish to bring before you is one who came under my care six weeks ago with an affection of the inner side of the ankle, which he attributed to a sprain two months previously, after which he had constant pain in the part, and increasing thickening of the textures. The outer side of the foot and ankle looked perfectly sound. We put up the limb in a side splint of poroplastic material, and used repeated blistering, but without any advantage ; pain continued to increase, and it was evident that, if left to run its course, it would end in caries of the tarsus. I therefore, fifteen days ago, made an antiseptic incision, expecting to open a joint, but hoping that I should not find pus. To make an opening into an articulation without the presence of pus would have been, without antiseptic means, an unjustifiable proceeding ; but here, as I have said, I hoped not to find suppuration, because I knew that, if the procedure were antiseptically conducted, the opening into the joint would do no harm whatever, while I should be able in all probability to get great benefit through relief of tension by free incision ; and if I should find that no pus had been formed, this would make the case much more hopeful, because it would show that the disease was not so far advanced as if suppuration had already occurred. I was gratified, therefore, to find, on cutting into the soft substance, which gave very much the same sense of fluctuation, before the incision was made, as if fluid had been present, that there was no pus—nothing but inflammatory degeneration of the soft parts, the lateral ligament between the astragalus and the navicular bone being entirely disorganized, so that when the finger-nail was applied the softened textures gave way with the utmost readiness, and the joint lay freely open before us, the cartilages happily appearing to be sound. I will now change the dressing, so that you may see the appearance of the part. While the bandage is being cut or removed, the patient, or an assistant, keeps his hand over the site of the wound, to prevent the dressing from rising *en masse*, and pumping in septic air. As I raise the folded gauze (exactly similar to that which I applied in the last case), I take care that the

spray passes into the angle between it and the skin. And now, Gentlemen, I venture to say here is a novelty for such of you as have not practised antiseptic surgery. There is the blood-clot still lying in the widely gaping wound, purposely kept open by this drainage-tube, which I introduced down to the open joint when I made the incision fifteen days ago, and which has never yet been taken out.

I have not seen this wound myself since I made it. I am sometimes accused of taking a deal of unnecessary pains with my cases, and it is also said that any good results which I may get are due to my own personal care. If such were the case, Gentlemen, if I obtained better results than other surgeons by the more careful use of the same means, that would indeed be something to be proud of. But it is not so. It is simply that we are working on a new principle. Mr. Rice, my house surgeon, who was trained first as a dresser and afterwards as a clerk under me, does these things exactly as I do them myself. If I were to go away for a week, a fortnight, or a month, as far as the antiseptic element is concerned, I should feel I had left my patients in perfectly safe hands. In this particular instance, Mr. Rice has had sole charge of the dressing after the first day, and here is the result. I am very glad to see, looking at the foot now for the first time for a fortnight, that the inflammatory thickening has almost entirely gone. I had of course made inquiry as to the patient's progress, and I had learned from his lips that the pain was greatly diminished, as the immediate result of the incision. I used to have a great horror of opening into the tarsal articulations in cases of this sort in consequence of the disastrous results which I have known to occur, through the spreading of suppuration among them. But if the skin is unbroken, so that the antiseptic system can be brought fairly into operation, there is no such danger. Here there has not only been no disturbance whatever from the operation, but we have obtained the benefit that we anticipated from free incision. The inflammation which previously existed has almost, if not entirely, disappeared.

And now let me direct your attention again to this remarkable appearance of the blood-clot lying in the open wound fifteen days old. If we had not used antiseptic means, that would have been impossible. Some people say, We can show you good results without antiseptic treatment. Of course, good results can be got by good surgery without antiseptic treatment ; but I say this is an instance of something that could not possibly happen without it. When a blood-clot existed in an open wound under a moist dressing which was not antiseptic, it was absolutely certain to putrefy and disappear long before the lapse of fifteen days. Let us now see what change may have taken place in this clot. I see, when I raise the upper layer of it from the edge of the wound,

that there is about an eighth of an inch of cicatricial margin ; yet there is no pus—there is not even any granulation. How the tissue which is thus formed in an organizing blood-clot differs histologically from that of granulations, I have not had time to investigate. But that it differs from granulations functionally is certain, and that in two ways. First, it has not nearly the same tendency to contract that granulations have ; and, secondly, instead of forming pus under the influence of the very slightest stimulus, as granulations do, this tissue resembles normal textures in requiring protracted stimulation to induce it to granulate and suppurate. Now, cicatrization in an open wound without granulation is something new ; it never happened in the world's history without antiseptic means.

We may now dispense with the drainage-tube in this case ; and having removed it from the tubular cavity in the coagulum in which it lay, I will cut out with scissors a piece of the tube of blood-clot. You observe blood oozes freely from it. What was once blood-clot bleeds when wounded. It has become organized and vascularized up to the surface.

If there had been a dressing of carbolic gauze applied next the wound, and changed daily, we should have had a very different appearance. It seems to be a difficult thing for me to write the English language so as to make my meaning intelligible. I find the opinion still often attributed to me, that carbolic acid stops suppuration by some sort of specific agency. On the contrary, I have pointed out, from my earliest experience in the subject, that antiseptic treatment threw remarkable light upon the subject of suppuration, by showing that an antiseptic itself, while it prevented putrefaction, stimulated to suppuration ; so that you have what I have termed 'antiseptic suppuration',[1] if the antiseptic continues to act upon the tissues for a certain length of time. If we had not interposed this layer of prepared oiled silk to protect the wound from the stimulating action of the carbolic acid in the gauze, we should have had a granulating and suppurating sore long ago. The blood-clot itself in its superficial layers serves as an additional protection to that which lies beneath ; but if the blood-clot, which must be regarded as a kind of tissue, is stimulated by an antiseptic, its superficial parts are converted in time into granulations which suppurate. The interposition of the oiled silk 'protective' shields the clot more or less completely from this stimulating agency, and, provided that you can allow a considerable period to elapse between the times of changing the dressing, so as to avoid the frequent washing of the clot with the stimulating antiseptic lotion, you may often see cicatrization proceed to its completion without any granulation occurring. In the present case, it is five days since the dressing was last changed, and it might have been left longer without risk

[1] See p. 152.

of putrefaction, the serous oozing being so extremely trifling. [The case had been dressed four times in all during the sixteen days that had passed since the incision was made, viz. on the day immediately following the operation (which, as a rule, should always be the case), and afterwards at increasing intervals, as the serous oozing diminished. But the deepest part of the dressing, consisting of the protective and the small piece of gauze immediately over it, had been left in place from first to last, to avoid as much as possible the stimulation of the clot. I may add, in preparing this paper for the press, that the case has continued to progress well. The patient told me yesterday (August 16), that the last trace of the jerking pain which he used to feel left him on the evening of the day of demonstration ; and Mr. Rice informs me, that, on changing the dressing on the 14th, after an interval of six days, he found cicatrization almost complete. We may therefore say, without much risk of mistake, that this foot has been saved from amputation by antiseptic treatment.]

The next case is one of ununited fracture in the lower part of the femur of a year's standing, in a man thirty-six years of age. Twelve days ago, I cut down on the outer side of the limb, a very long incision being required. Finding the fragments overlapping about an inch, I removed portions with the gouge and hammer from the posterior surface of the upper fragment and the opposing part on the anterior surface of the lower one, so as to leave two fresh osseous surfaces in apposition. Without antiseptic treatment, this would have been a very dangerous operation. The risk of pyaemia would have been so great, that, in common with most surgeons, I should have regarded such interference as unjustifiable ; but I think we may venture to say that, with antiseptic treatment in its present form, all such risk may be certainly avoided. It is now twelve days since the operation. For the first few days blood and serum were effused very copiously, and we had an arrangement by means of which a large mass of gauze could be applied in considerable extent under the limb. But the time has come when it might be put up in a more permanent form. This plaster-of-Paris arrangement was applied yesterday, while the limb was kept well extended by the pulleys, the patient being under chloroform. I have here a limited space for the dressing, and therefore use a correspondingly thick mass of gauze. This you will find often a matter of importance, as in operating for strangulated hernia, where you have not much space between the wound and sources of putrefaction in the perineum. And so in the present case, the window left in the plaster-of-Paris is occupied by a very substantial mass of gauze. The discharge of the last twenty-four hours has caused, you see, merely a small brownish stain upon the gauze, the result of a slight amount of serum, tinged with the colouring matter of the blood. The ends of the wound were stitched

up for about three inches at each side ; those parts united by first intention, and are completely healed. The central part of the wound was left open for the orifices of three large drainage-tubes. And here again we see the persistent blood-clot. Two days ago, I took out for the first time the drainage-tubes, and they were, just as in the case you last saw, lying in tubular moulds in the coagulum. One of them was permanently removed ; the other two were re-introduced after being considerably shortened by cutting portions off from the deeper ends. In taking out drainage-tubes you must be particularly careful to have the spray properly directed. For as the drainage-tube comes out, air must enter to take its place, and this air will be septic or not as the spray is or is not over the wound. Here we see the orifices of the two drainage-tubes, one of which may probably now be dispensed with altogether. As I remove them, you observe the tubular beds in which they lay. And here, as in the last case, we have as yet no suppuration whatever from the open wound.

The protective must never extend beyond the gauze ; if it did so, by excluding the action of the carbolic acid it would allow putrefaction to spread in under it.

I should have liked very much to have shown you one other case, but as time does not permit this, I shall mention in brief the main points of it. The case was one of chronic inflammation of the lower part of the tibia, which had induced great thickening of the bone, attended with severe and constant pain, in a girl eighteen years of age. There was a small sinus present, but scarcely any discharge. Introducing the probe, I found it pass deeply into the substance of the bone. Supposing that there might be some small exfoliation present, I proceeded to explore the bone, detaching the periosteum from the surface, and making an excavation with a gouge and hammer. I found a peculiar state of things pathologically. The chronic inflammation, instead of producing merely a softened state of the bone, had led to a conversion of the osseous texture into granulations. We operated by the bloodless method, and found these granulations almost perfectly white. I proceeded to dig these out, and got into cavity after cavity. At one time I thought the probe had gone through the posterior surface of the tibia, but it proved to have passed into another cavity in the extremely thickened bone. At last I found that the soft material at the lower part of the excavation moved when the foot was moved ; or, in other words, I had opened into the ankle-joint. The result of the whole procedure was a very large and complicated cavity, and it is to the mode in which this cavity has been filled up that I wish to direct your attention. Now, I desired that this should be done by means of organizing blood-clot. If this is done it saves a great deal of time as compared with granulation and healing from the bottom, and produces a more smooth and level scar. As for a long

time past I have done, I systematically placed the protective right across from one lip of the wound to the other, and then stretched the small piece of moistened gauze over, so as to keep the protective flat, in order that the blood-clot might accumulate under the protective, and so fill the wound. But we forgot to arrange the limb in proper position. It was allowed to lie resting on its posterior surface, and on changing the dressing next day I found that a large portion of the blood had drained out of the cavity. The deepest recesses of the excavation in the bone were indeed filled with clot, but a great cavity still remained. Well, there was an observation made by my colleague Mr. Chiene not long since that gave me a hint as to how to do in this case. He observed that, having systematically arranged for the formation of blood-clot in a hollow wound, a portion of the blood in his case, as in mine, trickled out, and the blood-clot only partially filled the wound. After the lapse of sixteen days, Mr. Chiene proceeded to ascertain by scratching with the point of a knife whether the blood-clot was organized. He found it was, for blood was effused from the vessels of the tissue into which it had become converted. Dressing was applied as before; and the remarkable thing is, that this secondary blood-clot, formed on the top of the first, became also organized like the first, producing living vascularized tissue level with the surface of the skin.[1] That observation gave me the hint how to deal with this case; for it showed that if the blood-clot is insufficient in the first instance, we may supplement it by letting fresh blood into it at a later period; and if the secondary clot became organized in Mr. Chiene's case, though formed so late as sixteen days after the operation, still more might such an occurrence be expected if the second bleeding took place at an earlier period. Accordingly, three days after this operation had been performed, I took a sharp knife and made a few slight incisions in the sides of the wound. A considerable quantity of blood poured out, and the limb being kept on its side, to prevent it from escaping, the result is that, twenty-two days after the operation, and nineteen days after this secondary procedure, I could show you still a portion of the secondary blood-clot visible, while the greater part of it has given place to granulations. [It may be added, that the patient has lost all her pain from the time of the operation, and that here, as in the case of disease of the foot and in the ununited fracture, there has never been the faintest inflammatory blush around the open wound.]

Demonstration II—Part I

Gentlemen.—The first patient I wish to show you to-day presents an illustration of the effects of ligature of an artery in its continuity by means of

[1] See *Lancet*, July 10, 1875

prepared catgut applied antiseptically. The opportunity of showing him to you, I owe to my colleague Mr. Annandale, under whose care he has been.

The case was one of aneurysm of the upper part of the femoral artery; but as it would not be right for me to anticipate Mr. Annandale in the publication of its details, I shall merely mention to you the main point that I wish to illustrate. The external iliac artery was tied under spray, the operation (at which I happened to be present) being performed with strict regard to antiseptic management, while the important matter of the use of drainage-tube was not neglected. The operation was performed on the 23rd of June, and the wound was absolutely skin-whole in fifteen days, without the occurrence of any suppuration at all.

[Mr. Furneaux Jordan, of Birmingham, was now kind enough to come forward and examine the patient, verifying the fact that there was no pulsation in the artery at the groin. Mr. Lister then proceeded.]

The immediate object of the operation has therefore been attained—the vessel has been permanently obstructed at the part tied; and this has been done without the occurrence of any suppuration, and by a mode which, I think we may venture to say, involves no danger whatever, provided it be properly carried out. The two great risks of an operation like this are, of course, secondary haemorrhage, and diffuse suppuration in the cellular tissue around the peritoneum; and both of these are securely guarded against by proceeding in this manner. I believe myself that this is a pretty perfect method of obstructing a vessel in its continuity; I do not see that we can wish to have it improved upon. I therefore regret extremely to find that it is still distrusted in various quarters, even by those who use catgut for the ligature of arteries in ordinary wounds. They do not trust it for tying arterial trunks in their continuity. I regret this the more, because I feel it is to a certain extent my own fault. When I first published on the subject, I was not aware myself of the proper mode of preparing the catgut. I had prepared it right, but by a mere accident. I described the mode of preparation in the *Lancet*,[1] as steeping the catgut in a mixture of carbolic acid and oil. It so happened that the carbolic acid which I used was liquid carbolic acid, so called—that is to say, crystallized carbolic acid, liquefied by the addition of water. Now, this water makes all the difference in the world. When oil is added to this liquid carbolic acid, a considerable portion of the water is deposited in the form of very fine particles, which are suspended in the oil; and it is this mixture—this emulsion if we may so call it—of oil and water which causes the remarkable physical change in the animal tissue of which catgut is composed, that alone renders it fit for our objects. The tissue of the

[1] See *Lancet*, April 3, 1869 (p. 86 of this volume).

catgut in the ordinary condition is utterly unfit for surgical purposes; as slippery, when moistened, as a piece of intestine in the dead-house—when you tie it in a knot, it slips with the utmost ease. But after it has been steeping in the emulsion of carbolic acid, water, and oil for a certain length of time, it undergoes a physical change, which I am quite at a loss to explain. As the tissue lies steeping in this mixture, the first effect is to moisten it somewhat; then, as time passes, after about a week, you find that, instead of becoming softer, more swollen, and more opaque, as you would expect, it is, on the contrary, growing less opaque and beginning to shrink; and in about three months, though still softer than dry catgut, it is comparatively firm, and quite transparent. Now, if you take a fresh piece of dry catgut and put it into this same sample of the preparing liquid, you will find the second piece become in the first instance partially moistened like the first; a fact which renders it inexplicable to me, why the former piece should have undergone what looks like a partial drying. But whatever the explanation, the all-important fact is this, that after the catgut has been thus partially dried, so to speak, in this moist liquid, it is now no longer liable to be made slippery by being steeped in water or the animal juices at the temperature of the body: it is indeed rendered softer and somewhat opalescent, but a reef-knot tied upon it holds better than one on waxed silk. I repeat, when I first published on the subject, I was not aware of this circumstance. I had got the catgut properly prepared, but it was by mere accident that the water which is essential to the process was present in the mixture that I used; and, ignorant of its importance, I omitted to mention it in the description which I gave of the mode of preparation; whereas mere steeping of catgut in a solution of dry carbolic acid in oil, though it of course makes it antiseptic, leaves it perfectly unfit for use as regards its physical properties. When I found out my mistake, I sought to remedy it by insisting, in subsequent publications, upon the importance of the presence of the water in the preparation of the catgut; but I never stated, as I now do, that I had originally described an untrustworthy method. I very much regret this bad result of what turns out to have been premature publication; and I earnestly hope that this public confession of my mistake will have the effect of preventing any further bad consequences from it.

The catgut does not spoil by being kept a long time in the preparing fluid of oil, carbolic acid, and water. Here is some that was put in six years ago last month. It is now just as good as ever. Thin as it is, I cannot break it with any reasonable force. If you were going to tie the external iliac, you would use a thicker piece than this; partly, in order that it may stand any strain to which it could be reasonably subjected in the act of ligature, and partly

that, a longer time being required for the absorption of the more substantial material, it may remain longer as a mechanical barrier to the force of the circulation.

[In this point of view there is another important advantage possessed by catgut properly prepared, viz. that it is much less rapidly absorbed than that which has been for a shorter time in the preparing liquid.

I would strongly advise any surgeon, who proposes to ligature an artery in its continuity with catgut, to test for himself the quality of the article ; since those who sell it are tempted, if their stock of old catgut has run out, to supply that which has not been long enough prepared. In order to ascertain if it is trustworthy, a piece should be steeped for an hour in water about the temperature of the body, as in a vessel at a suitable distance from the fire. If then a reef-knot tied upon it does not slip, it is fit for use. And it will be well for the surgeon to keep a stock of the material for special purposes like these, testing it in the first instance in the manner described, after which he will be sure that, being still kept in the preparing liquid, it will be at least equally good at any subsequent period. If these points are attended to, there will be no further complaints about untrustworthiness of the catgut.[1]]

I have now, Gentlemen, to bring before you two cases illustrating a somewhat interesting example of the usefulness of the catgut, namely, for the arrest of haemorrhage from a wounded vein.

Nineteen days ago I removed this patient's mamma, and at the same time cleared out the entire contents of the axilla, thus taking away, along with the fat, a number of scirrhous lymphatic glands, one of which lay immediately beneath the clavicle. In performing the operation, you may cut freely enough on the side towards the chest ; but towards the axillary vessels, the glands,

[1] When it is requisite that the cord should be able to withstand all the strain to which the human hands can subject it, as, for example, if it be used for the pedicle in ovariotomy (in which case, I may remark, the pedicle would have to be well subdivided), the material must be of specially strong quality to begin with. Catgut consists of the peritoneum, together with muscular fibres, of the small intestine of the sheep ; and the common kinds are either the entire tube of the gut, or longitudinal strips (according to the thickness required) simply twisted, dried, and subjected to sulphurous-acid vapour, or other chemical agents. But for special purposes, as, for example, the manufacture of fiddle-strings, the cord is made of several narrow strips twisted together, and is then very much stronger. Such catgut can be obtained of the musical-instrument makers, but is of course then unprepared in our sense, unfit for surgical purposes, and must be kept in the preparing liquid for a due length of time. For the sake of those who wish to prepare catgut for themselves, I may repeat here the proportions which I have found the best for the purpose. Add one measure of water to ten parts by weight of crystallized carbolic acid, mix and add one measure of the mixture to five measures of olive-oil, in a suitable jar or wide-mouthed bottle ; then at once introduce the catgut, the hanks being opened up to allow access of the liquid to them ; cover, and set aside in a cool place. Some water is gradually precipitated to the bottom of the vessel, and it is necessary to prevent any part of the gut from coming in contact with this precipitated water. A simple way of ensuring this is to put in as many marbles as will cover the bottom of the vessel.

with the loose tissue about them, should be detached with the fingers, and any considerable-sized venous branch tied before it is cut.

[If the incision is carried parallel to the margin of the pectoralis major to near its insertion into the humerus, and the integument is raised a little from the edge of the muscle, and also freely dissected backwards to the fold of the latissimus dorsi, there will generally be obtained satisfactory access for dealing in this manner with glands situated even at the apex of the axilla ; the pectoralis being drawn well forward, when necessary, by means of a copper spatula. If, however, the space thus obtained is not sufficient, whether for the removal of glands in that situation, or for the arrest of haemorrhage there, the skin should be at once dissected up from the pectoralis, and the muscle divided transversely from the margin towards the collar-bone to any degree that may be requisite. When I first adopted, seven years ago, the practice of systematically clearing out the contents of the axilla, I divided both pectoral muscles in all cases (the pectoralis major only partially), and though I have since found that this is not generally necessary, yet the experience of the earlier cases was valuable, by showing that the division of the muscles, though it appears a severe procedure, does not seriously complicate the operation, either as regards its performance or its ultimate results. The arm being kept bound to the side, the divided muscles unite quickly, and the patient gives, in time, the best evidence that their functions are not materially impaired by being able ‘ to do her back hair ’.]

In the present case, one of the glands was so very close to the vein that, as I was endeavouring with the fingers to detach it, a venous branch broke at its origin from the axillary, the result being an aperture in the venous trunk about an eighth of an inch in diameter. I seized the opening in the vein with catch-forceps, and put a catgut ligature upon it, but the thin slippery tissue of the venous coat slipped from the grasp of the knot. I made a second similar attempt, and again the same thing occurred. What was now to be done ? Without antiseptic treatment I should have been a good deal at a loss. To have obstructed the main vein of the limb by tying it across like an artery, would have been most undesirable ; and to have introduced a pad of lint into the wound, to compress the orifice, would have been very unsatisfactory practice.

I did, however, what I had long contemplated doing, if such a circumstance should arise. All flow of blood being temporarily stopped by pressure on the vein to the distal side, I threaded a fine sewing-needle with the finest catgut, and passed it through the coats of the vessel at opposite points of the wound, and at a short distance from its edges, and then, cutting off the needle so as to leave two threads in its track, tied one thread round each half of the wound.

The purchase thus secured upon the venous texture prevented the ligature from slipping, and the bleeding was permanently arrested. The healing of the wound has proceeded undisturbed, and cicatrization is, you observe, already almost complete. Here the small part that remains unhealed being entirely superficial, it is no longer needful to use the spray in changing the dressing.

Another reason that has made me bring this patient before you is, that you may see how the drainage of the axilla was provided for, and this I believe to be a matter of great importance. In all previous cases of this kind, when it was necessary to clear out the axilla, my practice had been to extend the transverse incision made for removal of the mamma, and introduce a drainage-tube at the outer angle of the wound. But if this is done, it will sometimes happen, if the patient be stout, that in spite of the presence of a substantial pad of folded gauze between the arm and the chest, the skin of the fat side and that of the fat arm will come in contact with each other, and the drainage-tube will become obstructed, leading to tension in the axilla, and, it may be, inflammatory suppuration. But here, for the first time, I have got over this difficulty completely, by making a special perforation for the drainage-tube so far back as to be out of the way of the pressure of the arm. Here, you observe, is the place where the tube was inserted, viz. in the angle between the arm (as it lies against the side) and the back. Thus, while you avoid a needlessly long incision, you have the most complete possible drainage, and the result, as you see here, has been very rapid healing. We all know that wounds after removal of the mamma may heal quickly, and sometimes without suppuration, without any antiseptic treatment at all. But this, I suspect, could not have been an instance of that kind. A large amount of skin implicated in the disease had been removed, so that, notwithstanding the use of button-stitches,[1] tension was great ; and if we add to this the presence of the large hollow wound in the axilla, it is not at all likely that under any treatment not antiseptic, healing would have occurred without suppuration, as it has done here.

The other patient whom I wish you to see, as an illustration of the arrest of venous haemorrhage by means of catgut, will now be brought in. She had long suffered from varicose veins, which you see conspicuous in the leg, even in the recumbent position in which she is ; and I was asked to see her on account of haemorrhage that had occurred from a tumour about as big as an orange, which had formed in the ham, the most prominent part being formed of blood-clot. It was evidently composed of a mass of greatly distended veins, one of which had given way by ulceration. The case seemed urgently to demand interference, and I resolved to remove the mass—a thing which I should have

[1] See *Lancet*, June 5, 1875 (p. 241 of this volume).

hesitated in doing without antiseptic measures, as I felt sure that I should open into large varicose veins. Such proved to be the case, as you see from this preparation of the part removed. On section, the most prominent portion is shown to be composed of coagulum, while the deeper surface presents numerous large vessels. They have shrunk a good deal since they were removed, but when the operation was performed they were almost as thick as my little finger. And now we have to speak of how the veins, which lay open in the wound, were dealt with. Some of them presented transverse orifices, but others had been divided more or less longitudinally. I tried, by detaching the veins from the surrounding parts, and clipping away some portions, to get the vessels to present themselves in transverse section, so that I might tie them with catgut in the ordinary way; and in most instances this was satisfactorily accomplished. But there was one large vein presenting a longitudinal slit about five-eighths of an inch in length, so connected that I could not readily deal with it as with the others. I therefore adopted a practice which will, I believe, prove a valuable addition to our resources, in wounds of large venous trunks. Using a very fine sewing-needle and finest catgut as before, I sewed the two lips of the wound together by continuous or glover's stitch; leaving the calibre of the vessel intact. Now, I do not think any man would have been justified in doing that with ordinary silk or cotton without antiseptic measures. To do so would have been to run imminent risk of suppurative phlebitis and pyaemia. But by proceeding antiseptically we incurred, as I believed, no such danger, and the result is, as you see, so far satisfactory. It is now three days since the wound was dressed last, and five days after the operation. The discharge of the three days has caused, you observe, a merely trifling serous stain upon the gauze. And there is entire absence of any inflammatory disturbance. In performing the operation, the skin having been very thoroughly washed with 1 to 20 carbolic-acid lotion, I took care to cut wide of the tumour, so as to keep clear of the putrefactive material on the exposed clot; but though a considerable portion of skin was thus taken away, I was able, by dissecting up the integument a little at each side, to free it so that its edges could be brought together closely by suture, except at the spot selected for the insertion of a small drainage-tube. You see the blood-clot still lying at this spot, while the stitches retain their places without any suppuration about them. [Healing afterwards proceeded to its completion, without gaping of the wound or any other untoward circumstance. It should be mentioned, that bloodlessness of the operation was provided for by encircling the thigh with a constricting elastic band, after emptying the limb of its blood by keeping it elevated for a few minutes in the vertical position.

AN ADDRESS ON THE TREATMENT OF WOUNDS

Delivered before the Surgical Section of the International Medical Congress, London, August 1881.[1]

[*Lancet*, 1881, vol. ii, pp. 863, 901 ; *Transactions of the International Medical Congress*, London, 1881, vol, ii, p. 369.]

Mr. President and Gentlemen.—To those of you who know from personal experience what antiseptic measures can do for surgery it may well seem strange to find some who have taken part in this discussion still assigning them a secondary place in the treatment of wounds. The explanation of this fact is, I believe, to be found chiefly in the success—nay, the brilliant success—sometimes obtained without the use of any antiseptic means whatever. This has been conspicuously the case with abdominal surgery, and especially with ovariotomy. Ovariotomy, indeed, has sometimes been spoken of as a touchstone of the efficacy of the antiseptic treatment. The success which has attended antiseptic ovariotomy has been regarded as a signal proof of the truth of the antiseptic principle. Such, however, has never been my own view. Mr. Spencer Wells and Dr. Thos. Keith achieved results which astonished the world before strict antiseptic treatment was thought of : and when, several years ago, Dr. Keith expressed to me an intention of performing ovariotomy antiseptically, I strongly dissuaded him from his purpose. I knew his already brilliant success ; I felt that our spray apparatus was as yet inadequate for the production of a cloud sufficiently large to cover the whole field of operation, and sufficiently fine to avoid needless irritation ; and I was also aware that such operations are often both very protracted and very anxious, while in proportion to the duration and the anxiety of an operation is the chance of the neglect of some apparently trivial yet important element in the procedure. And if the antiseptic treatment were attempted in ovariotomy and failed in its immediate object, I felt that it would be not only nugatory but injurious. It seemed to me that in any case of ovariotomy performed without antiseptic measures there was a contest between effusion from the wounded surfaces and absorption of the effused serum by the uninjured peritoneum. If absorption kept pace with effusion, there was no time for putrefactive fermentation to take place in the effused liquid ; but if absorption lagged behind and effusion predominated, the serum accumulated in the abdominal cavity, and, putrefying, gave rise to septicaemia. Now, supposing an antiseptic like carbolic acid to be employed in the operation, the peritoneal

[1] In preparing these remarks for the press, Mr. Lister has expanded the facts and arguments adduced during the necessarily limited time at his disposal in the discussion.

surfaces, as well as those of the wound, would be more or less irritated by it, and in proportion to this irritation would effusion be increased and absorbing power enfeebled, till such time as the temporary effect of the carbolic acid had subsided; and if, in spite of the antiseptic means, active septic matter had been introduced, putrefaction and septicaemia would be the natural result.

At the same time, I believed that the day would come when strict antiseptic treatment would prove valuable in ovariotomy. Especially did I anticipate that it would permit early operation for small tumours instead of the patient being kept waiting in anxiety, as used to be the case, till the tumour should have attained large dimensions. And in point of fact I think, judging from the records that have come to us from various quarters, and especially from Germany, that strict antiseptic treatment has rendered very great service to ovariotomy; that it has made the surgeon more independent of healthy surroundings, and also has made less essential the excessively minute care during the operation, and the close attention after it which we have all so much admired in the practice of Dr. Keith. Thus surgeons generally have been brought, by the use of antiseptic means, much more nearly towards the high level of Wells and Keith. Even Keith, on at length adopting strict antiseptic measures with an improved spray, for a while surpassed himself by an unbroken series of eighty successful cases. Yet, wonderful as this achievement was, it was only a difference in degree from his former experience, and assuredly no absolute proof of superiority of the new means employed. Of late I understand he has abandoned the spray for reasons which I had not the opportunity of hearing him explain when this subject was discussed at the Congress, and I am informed that he continues to have admirable results, which cannot surprise us when we remember what he had arrived at in his early period without adopting antiseptic measures.[1]

But how, it may naturally be asked, can the success of ovariotomy performed without the use of antiseptic means be reconciled with the truth of the antiseptic principle? The answer is, I believe, to be found partly in certain peculiarities of the abdominal cavity, and partly in circumstances common to wounds in general. One great peculiarity of operation-wounds within the abdomen, as compared with those in ordinary situations, is that already referred to—viz. that the plasma from the cut surface is poured out into a large cavity lined with a serous membrane disposed to absorb it as fast as it is effused. Thus without drainage or any outlet whatever for discharge being provided, the

[1] It is important to bear in mind that Dr. Keith always paid the most scrupulous attention to cleanliness; and among the elements of that cleanliness he included what was a very important antiseptic precaution—namely, the purification of the sponges which he used by boiling them; impure sponges being undoubtedly a very fertile source of septic contamination, while protracted boiling is a most effectual means of destroying septic ferments.

serum is, under favourable circumstances, prevented from accumulating as it would in ordinary wounds similarly treated, and opportunity is not afforded for putrefaction.

Another favourable result of the disposition of the parts is that even if some accumulation of fluid does take place, the large size of the cavity, naturally adapted for variations in capacity, prevents the occurrence of tension, which is so common a cause of disturbance in ordinary wounds. More especially if a large tumour has been removed, the part affected is left in a state of the most perfect flaccidity and relaxation.

A further peculiarity in favour of abdominal wounds is due to the high vital power of the peritoneum. I recollect making a post mortem examination in a case of strangulated hernia, where death had taken place within forty-eight hours of the operation, and finding it impossible to discover the site of the incision by inspection from within the abdomen, so completely had the peritoneal wound already cicatrized. This high degree of vital energy operates beneficially in a manner which I shall be better able to explain when I have spoken of some circumstances common to all wounds in their relations to septic agencies.

At the Cambridge meeting of the British Medical Association last year, I brought forward facts which showed that the serum of blood is not at all so favourable a soil for the growth of micro-organisms as I had previously imagined.[1] If we take a glass of uncontaminated milk or urine, so arranged that if left untouched it will remain for any length of time free from organisms, and add to it a drop of ordinary water, we are sure to find in a few days evidence of bacteric development in the liquid. Indeed, in the case of milk, which appears to afford pabulum for almost all varieties of micro-organisms, I have shown that if a dozen glasses of the liquid in a state of purity, in vessels suitably arranged to prevent contamination from without, receive each one-hundredth of a minim of tap water, most of the glasses will develop bacteria, though of different species in the different vessels, showing how numerous and how various are the micro-organisms really present in water.[2] Even the comparatively crude liquid which we call 'Pasteur's solution', a mere solution of cane-sugar, tartrate of ammonia, and earthy salts, in which many kinds of bacteria refuse to grow at all, will be pretty sure to produce such organisms in a few days if a drop of tap water is added to it. Now from these analogies, and knowing as we do to our cost that blood serum is but too liable to putrefactive fermentation, I had

[1] See vol. i, pp. 387 et seq.

[2] See 'On the Lactic Fermentation', *Transactions of the Pathological Society of London*, 1878 (printed in vol. i, p. 353). The results of such an experiment differ according to the season of the year. In cold wintry weather, when bacteria might be expected to be less numerous, it may happen that but few of the inoculated glasses show any change at all.

assumed that ordinary water contained putrefactive bacteria in a form that would develop in serum.

But when in the course of an experiment to be again referred to, I drew blood, with antiseptic precautions, from the jugular vein of an ox into a series of purified bottles, about half an ounce into each, and, having allowed the blood to coagulate and the clot to shrink, introduced various quantities of tap water to mingle with the expressed serum in the several vessels, I found, to my surprise, that not only an entire minim, but two, four, and even eight minims, failed to induce putrefaction, although the bottles were kept in a warm box at the temperature of the body. I have since confirmed this experiment in the ox, and have also extended it to the blood of other animals—the donkey and the dog—with similar results. I even found that putrid blood in full activity, if largely diluted with water purified by boiling, and introduced in small quantity in proportion to the serum, failed to occasion putrefaction or the development of any organisms that I could discover by ordinary microscopic examination. Yet the same quantities of the same dilutions quickly gave rise to putrefaction in blood of the same animal altered by mixing it with an equal part of purified water, showing that they really possessed septic energy, though unable to exert it upon normal serum. Not that the blood of these animals was in its natural state incapable of putrefaction, for inoculation with a very small quantity of undiluted putrid blood soon rendered it highly offensive. But the results of these experiments seemed to point to the remarkable conclusion that, after having been widely diffused by means of water, bacteria are incapable of developing in undiluted healthy serum. In this respect serum is totally different in its behaviour from milk, in which, as I have shown elsewhere,[1] a single *Bacterium lactis*, detached from others by a similar process of diffusion by means of water, is as sure to produce its kind as are a million taken directly from souring milk.

How it is that the diffusion of bacteria renders them incapable of developing in serum I do not profess to understand. It may perhaps be that when bacteria are introduced directly from putrid blood, the products of the putrid fermentation adhering to them may induce chemically an alteration in the normal quality of the serum which, when thus impaired, may prove amenable to the nutritive energies of the micro-organisms, while conversely copious ablution with water may remove from the bacteria the associated substances which thus act as their pioneers. This view might be otherwise expressed by saying that the bacteria *per se* are unable to grow in normal serum, and can only develop in that liquid when it has been vitiated, whether by the addition of water or by the action of small quantities of the acrid products of putrefaction.

[1] Vide *Path. Trans.*, loc. cit. (see vol. i, p. 373).

Or, again, it seems to me conceivable that the normal serum may oppose an insuperable obstacle to the nutritive attractions of an individual bacterium, but that this may be overcome by the associated action of several of the organisms in close proximity ; after the analogy of the more energetic operation of a concentrated solution of a chemical reagent. In this case the diffusion by water would produce its effect by simply detaching and separating the bacteria from each other. But whatever be the explanation, the fact remains.

I have also made observations on the effects of exposure of uncontaminated blood to air in different localities, and I have found that even the introduction of considerable quantities of dust has not led to putrefactive change.

Applying this knowledge to the discussion of ovariotomy performed without antiseptic precautions, the question naturally suggests itself whether in many cases any septic organisms have really been introduced into the peritoneal cavity, either from air or from water, in a condition capable of developing in the effused serum. And thus we have suggested to us a further explanation of the success of such operations.

But the facts which have been elicited by the experiments referred to have a far wider range of application than to the special case of ovariotomy. They seem to indicate that the putrefaction so apt to occur in wounds not treated antiseptically is due rather to septic matter in a concentrated form than to the diffused condition in which it exists either in water or in air. They suggest the highly important question, Is the spray really necessary ? In other words, Is there sufficient chance of the air of an operating theatre or private room containing septic matter which can prove effective in blood serum to make it needful to regard the question of contamination from the atmosphere at all ? If the answer must be given in the affirmative, and the choice must lie between the spray and antiseptic irrigation during the operation at intervals varying according to the discretion of the surgeon, with syringing of the cavity of the wound after stitching, and syringing also at every dressing, then I should give my voice decidedly in favour of the spray, as being more sure of attaining its object and involving less irritation of the wound, and also (if carbolic acid be the antiseptic used) much less risk of carbolic poisoning. At the same time it must be distinctly borne in mind that the spray is, beyond all question, the least important of our antiseptic means, and that the circumstance that a surgeon does not happen to have a spray-producer at hand is no excuse whatever for his abandoning the attempt to obtain aseptic results. But if the apparatus for the spray is at my disposal, I for my part do not as yet dare to abandon it. By the careful use of our present means, the spray included, we have arrived, I think I may venture to say, at absolute security of attaining the great object

in view, provided that we have the two essential conditions complied with : an unbroken skin to start with and the seat of operation sufficiently distant from any source of putrefaction to admit of adequate overlapping of the surrounding integument by the requisite dressing. I leave it to those who have done me the honour to visit my wards to judge whether I am guilty of exaggeration in making this strong statement. Such being the case, I should not feel justified, except on perfectly established grounds, in omitting any part of the machinery by which results so important to our fellow creatures have been arrived at.

Nevertheless I am aware that, concomitantly with the perfecting of the spray, there has been an improvement in other parts of our antiseptic arrangements, and I am not prepared to say that our increased uniformity of good results may not be due to the latter rather than to the former. And it may be, for aught I know, that when the International Medical Congress next meets I shall be able to speak of results of a still higher order obtained without using the spray at all. For if further investigation should confirm the conclusion to which our recent facts seem to point, and it should indeed be proved that all idea of atmospheric contamination of our wounds during operations may be thrown to the winds, then no one will say with more joy than myself 'Fort mit dem Spray'.[1]

The fact that normal serum is not made to putrefy by the addition of a small quantity of water came out unexpectedly in the course of an experiment designed to illustrate a view which I had long entertained as an inference from circumstances observed in surgical practice—viz. that an undisturbed blood-clot has a special power of preventing the development of septic bacteria. This property I ascribed to the white corpuscles, which are well known to retain their life long after blood has been shed from the body.[2] I supposed these living elements of the clot to produce this effect in accordance with a principle which I believe I happened to be the first to demonstrate, but which is now generally admitted—viz. that the tissues of a healthy living body have a power of counteracting the energies of bacteria in their vicinity and preventing their development.

The experiment which I related at Cambridge seemed to confirm this view completely. I have already described one part of that experiment, consisting of the introduction of small quantities of water into vessels containing uncontaminated blood after coagulation had occurred, and the clot had shrunk so as

[1] This is the title of a recent paper by Professor Bruns, of Tübingen, advocating the substitution of carbolic irrigation for the spray.

[2] Last autumn I observed amoeboid movements in white corpuscles from the buffy coat of a donkey's blood which had been for two days in a glass vessel.

to press out the serum. In the other part of the experiment the water was introduced before the blood into the purified bottles which were to receive it, so that any organisms which the water contained were diffused in the entire mass of the blood before coagulation, and were presumably retained in the clot when it shrank and pressed out the serum. And unexpectedly great as the resisting power of the serum to the development of micro-organisms proved to be, that of the coagulum seemed markedly greater. But our knowledge of the remarkable influence of the quantity of the ferment in proportion to the serum, as indicated by the more recent experiments, makes the evidence on which I relied at the Cambridge meeting far from conclusive,[1] so that I cannot now regard it as demonstrated for blood outside the body that the coagulum has a greater power than the serum of resisting putrefaction. But what I desire particularly to mention on the present occasion is an experiment with reference to the behaviour of the coagulum under the circumstances in which it especially interests us as surgeons—viz. within the living body. The experiment was of a character such as it would have been difficult under existing circumstances to perform in London, so I resorted to the École Vétérinaire of Toulouse, where everything was most liberally placed at my disposal by my friend Professor Toussaint and others in authority at the institution.

Having provided four pieces of glass tube, each about an inch and a half in length and three-hundredths of an inch in diameter, containing two pieces of silver wire (W) twisted together, with a little piece of fine linen cloth (L) fixed between them at their central part, the whole apparatus having been purified by steeping in a strong watery solution of carbolic acid, and subsequent boiling in water and drying over a lamp, I applied to each bit of linen one-twentieth of a minim of septic liquid, which was in the case of one of the tubes undiluted putrid blood, in the second that blood diluted with ten parts of pure (boiled)

[1] If septic liquid is diffused through blood before its coagulation, the bacteria are probably almost all, if not all, entangled in the meshes of the fibrine, and retained by them when the serum is pressed out by the shrinking clot. On the other hand, if the liquid of inoculation is added after the contraction of the coagulum, the bacteria are, in the first instance, confined to the serum. Hence, supposing the serum and clot alike in their resistance to bacteric development, we should expect, according to our present knowledge, that different results would follow such a comparative experiment, according as the serum was large or small in amount in proportion to the clot. Thus, when the serum is relatively scanty, as is the case with the blood of the ox, which was the subject of the experiment related at Cambridge, if a very dilute septic liquid were blended with the blood before coagulation, the bacteria, few in proportion to the bulky clot, might fail to develop in it; but if a corresponding quantity of the same liquid were dropped in after the clot had contracted, the bacteria, concentrated in the smaller quantity of serum, might succeed in growing in it. Observations of such a character cannot, therefore, be regarded as affording evidence of any special resisting power on the part of the coagulum as compared with the serum, unless an estimate is made of the relative amounts of serum and clot in the particular blood which is the subject of experiment, and a judgement formed accordingly.

water, in the third a dilution with a hundred parts of the water, and in the fourth a thousandfold dilution. I then exposed the jugular vein of a donkey in five places, with antiseptic precautions, leaving four intervening portions of the vessel intact and covered with the integument, and introduced into each undisturbed portion of vein one of the glass tubes with the septic rag in its interior, strong ligatures of string purified with carbolic solution being applied tightly as each tube was introduced, so as to form four venous compartments or capsules quite distinct from one another, and consisting of vascular tissue healthy at the outset.

After three days the animal was killed, and the venous compartments examined. In all four putrefaction had occurred within the glass tube ; but the state of the coagulum outside the tube was extremely interesting. I must content myself on the present occasion with referring to the condition of the first compartment, or that which had received the undiluted putrid blood. Immediately around the glass tube the clot was so much softened by putrefaction as to be almost diffluent. But next to the greatly thickened wall of the vein, and forming an adherent lining to it, was a layer of firm coagulum, in some parts about a quarter of an inch thick, resembling to the naked eye a perfectly recent clot. Before introducing the tubes into the vein I had drawn blood from it, with antiseptic precautions, into a number of purified stoppered bottles containing each the same quantity of septic liquid as the tubes received (1–20th minim) of various degrees of dilution, from the unmixed putrid blood to a mixture with 100,000 parts of boiled water. The bottles received each about as much blood as a venous compartment contained, and they were kept at the temperature of the body. Three out of four which had received the 100,000-fold dilution, as well as two kept uninoculated as standards of comparison, remained permanently free from putrefaction,[1] but those inoculated with larger proportions of the septic material putrefied, and those which received the undiluted putrid blood were, at the time when the vein was examined, in a state of utter decomposition, presenting a very striking contrast with the apparently unchanged layer next the wall of the vein.

But unaltered as this layer appeared to the naked eye, the microscope showed it to be in reality a very different structure from a recent clot. It proved to be teeming with cells of new formation, far more numerous than the white corpuscles of the blood, and differing from them altogether in characters ; being as a rule larger, and often of great size with pellucid contents, and having as their nuclei bodies more or less closely resembling pus corpuscles. On the day after the death of the animal and removal of the vein, I continued the

[1] The last observation was made nine days after the commencement of the experiment.

examination of the first compartment; and I was tearing off a part of the firm coagulum from the lining membrane when I opened into a little cavity in the clot about a quarter of an inch long and one-eighth of an inch in other dimensions, containing a thick liquid of pearly-white colour, the cavity having a thin grey lining separated by a layer of dark clot from the wall of the vein, except at one part. Here it communicated with a small venous branch, whose contents had been entirely converted into this white liquid for a short distance, beyond which the branch was obstructed by clot. On microscopic examination I found this white liquid composed entirely of closely packed corpuscles of new formation like those above described as infiltrating the clot. Here, however, the new cell development had taken place at the expense of all the original constituents of the coagulum, so that the fibrine had entirely disappeared, and only a stray red corpuscle here and there was to be discovered, and no granular débris was observed. The liquid was, in fact, neither more nor less than pus, and the cavity a small abscess. The evidence of endogenous cell development was in this liquid extremely striking. Many of the corpuscles resembled those of ordinary pus, though of varying dimensions; but often bodies exactly similar to the free pus corpuscles were seen still included as nuclei within large pellucid cells. In one such cell which I sketched there were four nuclei, three of which exactly resembled the free pus corpuscles. Thus I had the opportunity of repeating observations made in the course of very similar experiments carried on as early as 1864, experiments which, I believe, helped to prepare my mind for applying to surgical practice the conclusions of Pasteur as to the nature of putrefaction. Those observations have never yet been published, as I was compelled to suspend the investigation by the pressure of clinical work in connexion with the development of the antiseptic system. They proved, however, in the clearest manner that a blood-clot within a vein is, under septic influence, liable to a genuine suppuration—that is to say, to a change which is no mere result of breaking down of fibrine and accumulation of white corpuscles of the blood, but consists of a growth of living corpuscles multiplying by endogenous cell development at the expense of the original constituents of the coagulum.

As to the source of these newly formed corpuscles, we must suppose them to have been derived either from the white corpuscles of the blood or from proliferation of elements of the tissues of the wall of the vein. If we conceive them to have originated in white corpuscles of the blood, it is nevertheless quite certain that they were not mere emigrated white corpuscles, but that they had sprung from them as a new and altered progeny. The actual appearances presented favoured the view that the new cells had been derived from the

tissues. On examining stained sections[1] of the wall of the vessel and the adherent coagulum, I found that the corpuscles in the latter were similar in character to those which thronged the interstices of the tissue of the inner part of the vascular wall ; and among the latter were some that conveyed the idea of transition from the normal tissue elements. And this view seems confirmed by the fact that I have never succeeded in obtaining any new growth of corpuscles in coagulum outside the body, although the blood has been subjected to very various degrees of septic agency and has been kept in conditions similar to those within the body as regards temperature and moisture, and, indeed, in every respect, so far as I can judge, except only the influence of surrounding living tissues.

There was another circumstance observed in the clot within the vein which I must not omit to mention. Even the parts next to the lining membrane though not putrefying, had a distinct faint putrefactive odour. This is readily explained on physical principles by diffusion of the products of the putrefactive fermentation which was going on within the tube and in its vicinity. Indeed, one of the other venous compartments, on being opened, gave exit to a small amount of fetid gas, the remains of that which had been evolved from the putrefying part, and which had been only partially taken up by the surrounding parts ; but in the other compartments it had been all so disposed of. This diffusion of chemically irritating products of putrefaction beyond the limits of the actual septic process seems to me a matter of much importance ; and in the case of the ass's jugular it appears to explain, what otherwise might be difficult to account for, the inflammatory thickening of the coats of the vein, and also of the surrounding tissues. For the striking contrast presented between the inflammatory changes in and around the vessel in this animal and the entire absence of such appearances which I have found both in the horse and in the calf where I have tied the carotid artery antiseptically, with silk in the one case and with catgut in the other, seems to imply that the septic matter introduced within the vein of the donkey was the cause of the disturbance in question ; and the mode of its operation would seem to have been that above indicated.

But to return from this apparent digression. I have to add that, although twenty-four hours had passed since the vein was taken from the animal, I saw, in the course of a prolonged investigation of the pus in the little abscess, only a single bacterium. Also I have to mention the important fact that in the examination of the previous day, when the vein had been just taken from the body immediately after death, whereas in the softened part of the clot in the

[1] I gladly avail myself of this opportunity of publicly thanking M. Laulanier, the Professor of Anatomy in the École Vétérinaire, for his great kindness in preparing these sections for me.

vicinity of the glass tube the red corpuscles were utterly altered, and accompanied by abundant bacteria of different kinds, some in active movement, the piece of firm clot from near the wall of the vein showed the red corpuscles often exactly like those of freshly drawn blood ;[1] while, if any bacteria were present, they did not declare themselves to ordinary microscopic examination.

Thus the experiment affords very striking proof of the power of an undisturbed healthy coagulum in the vicinity of living tissues to resist the development of putrefactive bacteria, even when present in a highly concentrated form ; while we have, as I believe, an explanation of this power in the multitude of new living elements with which the clot was peopled.[2]

Turning now to the application of these pathological facts to ovariotomy, we find that they seem to complete the explanation of the success which has attended that operation performed without antiseptic precautions. Among the points in Dr. Keith's earlier practice which most excited alike my admiration and my astonishment was the way in which he diagnosed an accumulation of fluid in the pouch of the peritoneum termed Douglas's space, and, drawing off by puncture per rectum with cannula and trocar a quantity of putrid liquid, saved his patient from impending death. I greatly admired the skill of this practice ; but I was astonished at the pathological facts. How was the septic process limited and prevented from spreading throughout the cavity of the peritoneum ? This seems now to admit of interpretation. In such cases septic matter must have been introduced during the operation in a form capable of developing in the blood ; and if we suppose a portion of such effective septic ferment imprisoned in the interior of a coagulum in the space referred to, this clot, situated within the living body, may be conceived to oppose an obstacle to the development of the putrefactive bacteria in its substance, as was the case in the venous compartment of the ass's jugular. And here the high vital energy of the peritoneum would come into play. We have seen how rapidly a wound in the peritoneum may heal, and this rapid healing is, in other words, the rapid peopling of the lymph in the wound with vigorous new living elements. For, whatever view may be taken as to the source of these new corpuscles,

[1] The only change observed in the red corpuscles of this part of the clot was that in some cases they had an abnormal purple colour, which I presume was due to products of putrefaction diffused through the clot from the neighbouring putrefying parts.

[2] The development of cells of new formation in organizing coagula within the living body, first ascertained, so far as I am aware, by myself in 1864, has been the subject of various observations of late years, especially by German pathologists, as, for example, Tillmanns. (Vide *Centralblatt für Chirurgie*, 1897, No. 46.) That this cell development may, under some circumstances, go on to genuine suppuration is a fact I believe not hitherto published by any pathologist, though the truth of the occasional conversion of coagula into pus has always seemed to me sufficiently apparent from the naked-eye appearances of suppurative phlebitis and the beautiful experiments of Cruveilhier.

certain it is that the organization of lymph proceeds more rapidly in proportion as the wounded tissues are in a more vigorous condition. Thus a wound on the dorsum of the foot of a feeble old man, though strictly protected from septic influence, heals very languidly; while a cut in the lip of a child unites with great rapidity. This, indeed, would seem a further argument in favour of the tissues being the source of the new corpuscles. But be this as it may, the lymph on the peritoneum becomes very rapidly thronged with new living elements, and the same will be the case with a blood-clot, which differs from recent lymph merely in containing the additional and probably entirely neutral element of the red corpuscles. But in the meantime, as, in the ass's jugular, the tissues of the vessel were irritated, as it would appear, by the acrid products of putrefaction diffused around the septic parts of the clot, and penetrating to those which were not really septic, so would the parts of the peritoneum surrounding the clot in Douglas's space be excited to adhesive inflammation, gluing the opposed surfaces together by lymph; and again this lymph, becoming rapidly organized through the high vital energy of the peritoneum, would oppose an effectual barrier to the spreading of bacteric development should it extend to the surface of the clot. At the same time the irritation caused by the putrid products, where most intense, would induce copious effusion of plasma and accumulation of putrid serum. In time this state of things would lead to limited abscess, such as has been occasionally met with after ovariotomy, the discharge of the putrid pus having in some instances been followed by the recovery of the patient.[1]

But the power of organizing blood-clot or lymph to resist the advancing development of putrefactive bacteria has, like the behaviour of the serum in relation to putrefaction, a far wider range of application than to the explanation of the success of ovariotomy performed without antiseptic treatment. It serves, for example, as I believe, to explain a fact like the following: In Mr. Syme's celebrated case of diffuse aneurysm of the axillary artery, treated by 'the old operation', the aneurysmal clots had not only enormously distended the axilla, but reached backwards so as to raise the scapula, and upwards high above the

[1] It is conceivable that, even without the intervention of a coagulum, a collection of serum in Douglas's space, undergoing gradual putrefaction through the influence of some effective septic particle introduced at the operation, and being prevented from diffusion through the general peritoneal cavity in the first instance by a state of perfect repose of the patient, might by its irritation cause such adhesive inflammation as would prove an effectual barrier against the spreading of bacteric development; for the putrescent serum would produce inflammatory disturbance not merely in the parts on which it acted directly, but also by sympathy (through the nervous system) on parts in the vicinity. The serum of the plasma effused through this agency would be absorbed by neighbouring healthy parts, leaving the lymph to glue the peritoneal surfaces together, and, becoming rapidly organized, to operate as a vital barrier against the advance of putrefaction.

clavicle. He entrusted to me the duty of compressing the subclavian artery; and, as a preliminary measure, made a small incision penetrating through the deep cervical fascia, so as to enable my thumb to be thrust through the mass of clots in that situation, and reach the first rib, on which the vessel lay. He then laid open the mass in the axilla by a free and rapid incision, and scooped out with his hands enough of the clots to enable him to gain access to the arterial trunk, and tie it above and below the place of its communication with the aneurysmal cavity. Making no attempt to remove the rest of the coagula, which indeed would have been quite impracticable, he simply brought the cutaneous margins of the wound together by interrupted sutures, the ends of the silk ligatures being left hanging out of the wound, in accordance with the then universal practice; and as this was before the days of antiseptic management, no special treatment of that kind was of course employed, but a dressing of dry lint for the first few days, and water dressing afterwards. Considering the well-known danger of diffuse suppuration, which without antiseptic treatment used to attend free incision into a mass of extravasated blood, I was astonished to see both the puncture above the collar-bone and also the main wound heal in the kindest manner, without more suppuration from the latter than must have attended a wound made in healthy tissues as a consequence of the presence of the ligatures. The fact now ceases to be wonderful if we take into account the circumstance that the outlying clots had been for several days among the tissues, and had thus naturally acquired new living elements which would confer upon them the power of fencing themselves against advancing putrefaction.

Our principle seems, however, to find its widest application in aiding to explain the possibility of union by the first intention without the use of any antiseptic means, nay, in spite of the application of septic ones. For such is, in truth, the apparently cleanly water dressing. As certainly as we remove it from a wound after the lapse of twenty-four hours, do we find that the diluted blood serum which then soaks the lint has a putrid smell, implying that it contains septic ferments such as would assuredly act effectively upon blood outside the body. And yet, in the not uncommon case of the occurrence of primary union under such treatment, putrefaction fails to spread into the wound; for if it did so it would inevitably provoke suppuration.

Long before I entertained the idea of the antiseptic principle I often contemplated with wonder the behaviour of a thin layer of lymph or coagulum between the surfaces of a healthy wound, as contrasted with that which the same material would have exhibited, had it been placed in similar conditions as to temperature and moisture, between two sheets of glass or gutta-percha.

The absence of putrefaction in the former case, as compared with its occurrence in the latter, was plainly due in some way or other to the influence of the living tissues, between which the putrescible lymph or blood-clot lay. Beyond this, however, all was mystery. Afterwards, when the power of healthy living tissues to oppose bacteric development became apparent to me, as exemplified by the inability of bacteria to grow in the mucus of a healthy urethra,[1] I attributed the absence of putrefaction in the healthy wound to a direct control on the part of its tissues over the septic bacteria. There is, however, a defect in this explanation—viz. that, whatever be the nature of the controlling agency of the tissues on the bacteria in their vicinity, it can hardly be conceived that it is exerted beyond an extremely limited range ; so that in order that it should be effective, a more accurate and close apposition of the cut surfaces would seem necessary than actual experience shows to be required. And here our new principle comes to our aid, when we learn that the clot itself, as it becomes organized, acquires the defensive property which remained to be accounted for.

The thinner the layer of the clot, the more rapidly, *caeteris paribus*, will it be densely peopled throughout with the new corpuscles, which confer upon it this defensive power ; and the process will also advance quickly in proportion as the tissues of the cut surfaces are vigorous and active. And thus we have the *rationale* of the rules of the older surgery in aiming at union by the first intention—viz. to perform the operation as much as possible by clean cuts with a sharp knife that shall injure the tissues as little as may be, apply the cut surfaces closely together, at the same time providing an outlet for effused blood and serum, and afterwards endeavour to avoid inflammatory disturbance, which, in proportion to the degree in which it exists, enfeebles the vital powers of the part affected.

Yet sound as these maxims were in the then existing state of surgical science, the best efforts of the surgeon were too often thwarted by ‘ unhealthy actions ’, as he termed them, of which he did not understand the cause, and which he was consequently powerless to prevent. And we must not allow an exceptional case like ovariotomy to blind our eyes to the truth that the disasters of surgery in the past have been essentially caused by septic agencies.[2] Simplification of our means of procedure is no doubt in itself highly desirable, and I have already indicated one direction in which it may possibly be attained. But the safety of our patients incomparably transcends such a consideration, and it would indeed be a grievous thing if our desire for simplicity should induce us

[1] See *Transactions of the Royal Society of Edinburgh*, vol. xxvii (see vol. i, p. 275).

[2] Under the term ‘ septic ’ I of course include all unhealthy conditions due to the development of micro-organisms, whether the changes which they occasion in the organic fluids and solids be or be not accompanied by putrefactive odour.

in any degree to relax our efforts to carry out the strict antiseptic principle, the strenuous endeavour so to deal with wounds as to prevent from first to last the development in them of pathogenic organisms.[1] The means by which this object may be most surely and at the same time most conveniently attained will, no doubt, vary greatly in the future in accordance with our ever-advancing science ; but whatever modifications we may admit in our methods, let us at all events never be satisfied with any that does not yield results at least as good as those which it is now in our power to secure.

If we suffer ourselves to be drawn aside from the strict antiseptic principle, we shall not only subject our patients to the risk of the old disasters, but we shall be compelled to withhold from them the benefit of valuable procedures which strict antiseptic management alone can warrant. Take as a single example the case of a loose cartilage in the knee-joint. To remove it by free incision is the most simple and satisfactory treatment, except for the attendant danger which was formerly so great as to be prohibitory, but of which our present means of carrying out the antiseptic principle have entirely disarmed it. If such a procedure was ever ventured on without antiseptic means, the only chance of success lay in accurate closure of the wound with a view to primary union. On the other hand, under antiseptic management, I systematically abstain from closing the wound completely, leaving a part unstitched for the introduction of a drainage-tube, so as to guard against the inflammatory disturbance which might otherwise result from accumulation of fluid in the articular cavity. In other words, I abstain from the only means which would have afforded hope of success without antiseptic treatment, and I adopt means which, without antiseptic treatment, must infallibly lead to disaster through septic suppuration of the articulation. Here, then, I conceive we have a true touchstone of the truth of the antiseptic principle. The loose cartilage which I hold in my hand was removed from the knee of a gentleman a fortnight ago. It lay imprisoned in the angle between the anterior part of the articular surface of the tibia and the femur. I extracted it by free incision ; and as the situation was one which did not admit of convenient insertion of a drainage-tube into the joint, I left the wound widely gaping throughout. That patient has not since experienced the slightest uneasiness, nor has there been any disturbance, local or constitutional.

And this leads me to make the general remark that under strict antiseptic treatment union by first intention has no longer the importance it used to possess. As regards the essential points of avoidance of inflammation and fever, of pain

[1] The term 'pathogenic bacteria' has been introduced by the German pathologists to signify bacteria which give rise to disease in the animal body by developing within it.

and danger, it is a matter of absolute indifference whether primary union occurs or not. Nay more, as in the case just referred to, if we wish to make doubly sure of preventing all inflammatory disturbance, it is sometimes well to avoid stitching, and the tension which may become associated with it. There is at present in King's College Hospital a man on whom I operated three weeks ago for ununited fracture of the humerus, cutting down on the fragments and uniting them by a suture of thick silver wire after sawing off their extremities. Now, in a case of this kind some years ago in which I applied stitches to the wound, although a good-sized drainage-tube was used, a certain amount of inflammatory disturbance occurred, which I could only attribute to want of sufficient exit for the abundant sanguineous oozing that took place from the osseous surfaces. This disturbance led not merely to some deep-seated suppuration, but to necrosis of a portion of one of the fragments, which greatly retarded the cure. Hence I have since abstained from anything like close stitching after such operations, and in the patient referred to the wound was left gaping widely. At the next dressing it was found occupied by blood-clot, which has subsequently become organized, and at the same time has contracted so much that the cicatrix, already nearly complete, promises to be little more than linear. Meanwhile there has been no uneasiness, redness, or swelling, and no febrile disturbance, and if any imperfect pus whatever has been formed, it has been only from the surface of the organized coagulum as a result of slight unavoidable stimulation by the antiseptic used in the dressing. And here we have, as I believe, another touchstone of the antiseptic principle, showing that it is true, and gives results both new and important. For without effective antiseptic means of some kind or other such a course of such a wound would, I believe, be impossible. The impermeable protective layer applied next the wound under the antiseptic gauze prevented evaporation, and maintained a constant state of moisture of the surface of the clot. Now, a moist dressing other than an antiseptic one could not have failed to occasion putrefaction of the exposed coagulum and suppuration of the cavity of the wound.[1] Yet, all who are

[1] In an animal like the donkey the reparative energies of the tissues would appear to be greater than in man, as is indicated by the well-known facility with which healing by scabbing is obtained in veterinary practice. Yet, in the donkey's jugular, it was only the parts of the coagulum near the wall of the vein that had escaped putrefaction. Even in such an animal, therefore, an exposed clot covered with water dressing would putrefy, with the exception of the parts next the tissues ; and these would granulate and suppurate. Under a dry dressing, indeed, even in man, healing without suppuration has been sometimes seen in open wounds of considerable extent, especially when the affected part has been kept completely at rest and supported by methodical compression, as insisted upon by M. Alphonse Guérin and Mr. Gamgee. Here the dry dressing appears to have an antiseptic influence by causing an inspissated state of the serum in the dressing, for it has been shown by Naegele that bacteria are unable to develop in concentrated organic solutions. Such results of mere dry dressing cannot, however be reckoned on with anything like certainty.

familiar with antiseptic practice know that it is a common thing to see the organization of the blood-clot proceed under the protection of the superficial layer of coagulum to complete healing without a particle of suppuration, a scar being found when the superficial layer is detached.

Time would not permit me to refer to all that has been communicated by those who have taken part in this discussion. I cannot, however, forbear making a passing allusion to the extremely remarkable results which have been related by Professor Esmarch as obtained by his permanent dressing—results so surprising that they would be incredible were it not for the perfect trustworthiness of the authority that vouches for them. And I would ask those who advocate mere cleanliness, as distinguished from antiseptic practice, how they can reconcile their views with facts such as these ? What can be more dirty, in the ordinary acceptation of the term, than a wound left covered up with the same dressing for weeks together, the original blood and serum remaining upon it intact under this 'Dauer-Verband' ? Yet it is surgically clean because it is aseptic. On the other hand, the aesthetically cleanly water dressing is surgically dirty, because it contains elements which give rise to septic changes in wounds.

One other point which has been referred to in connexion with this debate is of so much importance that I cannot but notice it. The old objection has been revived that antiseptic treatment leads the surgeon to concentrate his attention upon local measures, to the neglect of general hygienic arrangements and a due consideration for the constitutional state of the patient before subjecting him to operation. I do not think that this charge is at all warranted by facts. For my own part, I have from the first used antiseptic treatment even for superficial wounds and sores, not so much for the sake of the individual cases (which I knew did well, as a rule, under water dressing) as for the express purpose of preventing them from contributing elements of general unhealthiness to the hospital ward. And if I have sometimes allowed the beds under my charge to be more crowded than is in accordance with the views of modern hygiene, it has been only after such a condition, originally brought about by accidental circumstances, had proved as a matter of fact consistent with perfect healthiness of the patients. The septic element being suppressed, less space was found to be essential to salubrity.

As to the other part of the charge—viz. that antiseptic treatment leads to a less careful selection of patients for operation than ought to be made, it seems to me to be refuted by the success which confessedly attends the practice. If, indeed, the charge were well founded, and we did really operate upon patients whose constitutions rendered them unfit subjects for such interference, good

general results obtained under circumstances so highly unfavourable would afford the most conclusive proof of the value of the local treatment employed. But the truth is, that the suppression of the septic element enlarges the capabilities of surgery in the constitutional direction no less than in the local ; and enables us to extend the benefits of needed operations to patients whose constitutions are so enfeebled by age or vitiated by disease that without strict antiseptic treatment no prudent surgeon would venture to meddle with them.

I appeal to the logical faculty of this great assembly of eminent men, and beg them to consider carefully in relation to this question the familiar case of a simple fracture or dislocation. Do we feel anxiety regarding the state of the constitution of a patient who has received such an injury ? The mischief done is in itself of a worse character than the surgeon ever inflicts. Yet so long as the unbroken skin shields the bruised and lacerated tissues from the access of materials coming from the external world, repair advances safely, no matter what be the constitutional condition ; the exceptions being so extremely rare that we practically leave them out of consideration altogether. It therefore surely follows that if we could contrive a treatment of our wounds which would have all the advantages of the unbroken integument, we might operate without anxiety on account of the constitution.

To provide a condition of our operation-wounds that shall put them fully on a par with subcutaneous injuries is plainly the ideal of our art. Towards the attainment of this ideal we have already made large progress ; and towards its full achievement, so far as it be possible, I would earnestly invite the best efforts of my hearers.

AN ADDRESS ON CORROSIVE SUBLIMATE AS A SURGICAL DRESSING

Delivered at the Opening Meeting of the Medical Society of London, October 20, 1884.

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Mr. President and Gentlemen.—When, in an address delivered at the opening meeting of last session,[1] I expressed myself in what some of my hearers regarded as terms of overweening confidence in the trustworthiness of antiseptic treatment, I little thought that, a year later, I should have to tell you of failures on my own part ; yet such is the case. Several instances have occurred, within the last few weeks, of results deviating from our typical experience in antiseptic treatment, such as I was in no way prepared to meet with, and, in one case, a fatal event ensued. A lady, on whom I operated for scirrhus of the mamma, with removal of the axillary glands, died of a spurious pyaemia, or a variety of septicaemia, an occurrence such as I have not met with for many years past. We dressed the wound in the usual way. Two days after the operation, there was pus already present at the anterior part of the incision. There happened to have been an unusual flow of blood at this part, where we do not, as a rule, expect much. It is a very unusual thing for pus to appear so early. We used to say, in what I may term the pre-antiseptic days, that, if we operated upon sound tissues, suppuration occurred, provided primary union did not take place, in from three to four days, three days in children, four days in adults, and, perhaps, in warm weather, rather earlier than four days. For pus to occur to the amount of several drachms at the end of two days was, therefore, very unusual, and some special form of organism, I have no doubt, was present. Micrococci were, indeed, found after death in abscesses which had formed within the pleura. Nevertheless, though I believe some unusual organism was present, we have been accustomed to consider ourselves free from the apprehension of such ill effects ; and though, I am thankful to say, no other fatal case occurred, there have been several instances of deviation from the typical course, where, instead of union without suppuration at all, we have had healing retarded by the formation of more or less pus, undoubtedly of a septic character, in the sense in which we now use the term septic, that is to say, dependent upon the development of micro-organisms, although no smell was perceptible. Now, sir, I need hardly say that one such result as that to which I have referred,

[1] See p. 453 of this volume.

a fatal event under circumstances which we had been accustomed to consider absolutely free from danger, made me reflect most seriously; and the other cases, though less disastrous, were also grave cause for reflection.

In looking for the source of our misfortunes, it was to the external dressing that we naturally turned our attention. The experiences of Mr. Cheyne and Professor Ogston indicate pretty distinctly that the means which we ordinarily use are sufficient for the purpose of rendering our wounds free from mischievous micro-organisms at the time we put on our dressings. Both Mr. Cheyne and Professor Ogston have found, by using the most advanced methods of investigation, that if a carbolic-acid gauze dressing is changed daily, no organisms are met with in the discharges. That, I say, seems pretty conclusive evidence that the means which we have adopted hitherto for the purpose of keeping our wounds pure, up to the time when the dressings are applied, are sufficient. With regard to our external dressings, our suspicions tended to turn upon the eucalyptus gauze. Eucalyptus oil is undoubtedly a powerful antiseptic, and I have been using it in the form of gauze for a considerable time past. One difficulty with it is its great volatility. In the first instance I employed gum dammar, instead of common resin, in the manufacture of the gauze, because I found that gum dammar held the eucalyptus oil more securely than the resin does; but gum dammar is an expensive gum, and, after some trials with common resin, I thought I was justified in substituting the cheaper material, and for a while we seemed to get good results with this arrangement. But, as I have already said, more recently the results were not satisfactory. I mean that, now and again, a case occurred which was unsatisfactory. On making inquiry of the manufacturer of our eucalyptus gauze, I found that he had deviated from the instructions which he had received as to the manufacture; that he often left the gauze, for a considerable time after it had been charged, exposed in the air before folding it up, thus affording opportunity for the escape of the volatile constituent in large amount; and in hot weather, such as that during our recent summer, this was more especially apt to occur. We found, as a matter of fact, that the eucalyptus gauze supplied to us had not the softness which it ought to have, caused by the adequate amount of eucalyptus oil. I was thus led to attribute our disasters to imperfection in the manufacture of the eucalyptus gauze.

These circumstances led to a reconsideration of the subject, and to an appreciation afresh of the disadvantages of any volatile antiseptic substance. Volatile antiseptics have their own advantages, to which I need not refer, but they have great disadvantages. In the first place, we are at the mercy of our manufacturer. The resin and paraffin so glue the folds of the gauze together, if it is allowed to

cool in mass, that it must be opened up while warm, and upon the way in which this is done by the manufacturer much depends as to the quantity of the antiseptic present in the gauze. In the next place, a volatile antiseptic, such as either carbolic acid or eucalyptus, has the disadvantage that it requires careful treatment by the surgeon himself. The material containing it must be kept in well-closed metallic vessels ; otherwise evaporation soon impairs its qualities. And in the third place, there is this disadvantage attending all volatile antiseptics, that the longer the dressing is kept upon the body the less efficacious does it become ; and who is to say when the time arrives when it has become so inefficacious that it is necessary to remove it ? I have been accustomed to regard a week as the limit of the time during which a carbolic-acid gauze dressing may be regarded as effectual ; but, beyond the fact that with this period our results were on the whole satisfactory, we had not what we may call precise grounds to go upon. In that respect, a volatile antiseptic must always be at a disadvantage, as compared with a non-volatile one, which will be just as efficacious at the end of a month, or six weeks, as it is when first applied, provided it is not soaked with the discharge.

Salicylic acid is a non-volatile antiseptic ; but salicylic acid, as I ascertained from experiments, several years ago, is very far from being as powerful in antiseptic qualities as carbolic acid, and therefore I have never ventured to use it for serious cases. Iodoform, while volatile, is very slowly volatile, and, at the same time, so little soluble in the discharges, that in these points of view it seems an admirable antiseptic ; but iodoform is by no means a potent agent in its action on micro-organisms. I ascertained, some years ago, for example, that, taking a 10 per cent. iodoform wool, the strongest used, and soaking this with milk, the lactic fermentation was only a short time retarded, and in the course of a few days not only the *Bacterium lactis*, but multitudes of other kinds of bacteria were seen, in abundance, in the milk. Again, uncontaminated urine being made to soak such a piece of wool, and then inoculated with putrefying urine, I found that the ammoniacal fermentation was only a short time retarded by the iodoform. Hence I was not surprised to learn that, in the practice of Schede of Hamburg, and others, it had been found that erysipelas occurred under the iodoform dressings. It is remarkable that iodoform has such an effect as it has in preventing putrefaction, but it is by no means a powerful germicide.

But there is another non-volatile antiseptic, corrosive sublimate, to which attention has been more especially directed of late years by Dr. Koch ; and here I may be permitted to give my tribute of praise to the admirably conceived and conclusive experiments which he has performed upon this subject. Koch

proceeds in this sort of way[1]; he dips a very small piece of silk thread into a fluid containing the spores of the *Bacillus anthracis*, known to be highly resisting to the various agencies inimical to low organisms. After this silk thread has become dry, he dips it in the antiseptic solution to be tested, keeping it there for a minute, half a minute, five minutes, or any length of time that is required. He then, by means of water or alcohol, or some fluid known not to influence the vitality of the spores, washes away the antiseptic from the thread, and brings into play his beautiful method of solid culture-material. He places the little bit of silk thread upon a piece of gelatine properly provided with nutritious material, and of course scrupulously pure, and observes, by means of the microscope, whether the spores in the silk thread develop or not. He ascertained, by experiments of this character, that a solution of only one part of corrosive sublimate in 20,000 parts of water was amply adequate absolutely to destroy the vitality of the spores of the *Bacillus anthracis*, about the most resisting spores that are known. But he found also that as weak a solution of the sublimate as one to 300,000 parts of a solution of extract of meat was sufficient to prevent the development of the spores so long as they remained in it; but when the silk thread, having been for any length of time in this exceedingly weak solution, was withdrawn from it, washed, and then placed upon the nutritious gelatine, development occurred as if the spores had not been exposed at all to any injurious agency; and thus Koch established in a most definite manner the distinction, and a very important one it is, between two different effects of antiseptic agents—one, the action by which the vitality of organisms is destroyed; and the other, that by which development is simply arrested, or prevented temporarily from occurring, without the vitality of the spores being interfered with. The former we may term ‘ germicidal action ’. For the latter, it is somewhat difficult to find a good English term. I happened, I believe, to be the first to use the word ‘ inhibitory ’ in English physiology, by the advice of my old friend Dr. Sharpey, with reference to an early paper I was about to publish on what the Germans term the ‘ Hemmungs-Nervensystem ’[2]; and as this same word *Hemmung* is used by the Germans for this checking or suspending action of antiseptics, without destruction of vitality, and as it is very important that we should have some term which distinguishes the one action from the other, I may venture to employ this same word ‘ inhibitory ’—a good old English word—for this action of antiseptics, and to speak of their ‘ inhibitory action ’ as distinguished from their ‘ germicidal action ’.

Now, these properties of corrosive sublimate were such as no other antiseptic

[1] Vide ‘ Desinfection ’. Von Dr. Robert Koch. *Mittheilungen des Kaiserlichen Gesundheits-Amtes*, 1. Band, 1881.

[2] See vol. i, p. 87.

agent had ever been ascertained to possess in anything like such dilute solutions. With regard to our purposes in antiseptic surgery, the inhibitory action of the antiseptic would be sufficient, provided we be satisfied that our wound is left free from injurious organisms, and that the dressing which we apply itself contains no such organisms still alive. Then, all we require is that the dressing should be able to prevent the development of organisms from without into the discharges with which the dressing may be soaked. That is obvious.

Corrosive sublimate has been used extensively already by our German brethren, chiefly in the form of sublimate wood-wool, as it is called, in which one-half per cent. of corrosive sublimate, with an equal part of glycerine, is mixed with what is termed 'wood-wool', namely, pine-wood reduced almost to a state of powder by suitable machinery. This is highly absorbent. It is employed in large masses, and, so used, has given many excellent results. At the same time, it is somewhat unwieldy in its application. Under certain circumstances, it is not convenient to have so large a mass as is essential for its safety, and we have also varying reports as to its efficacy ; and I may remark that we find some surgeons satisfied with what others would regard as a very mediocre kind of success with antiseptic treatment.

The circumstances to which I referred at the beginning of my address naturally made me turn my attention to corrosive sublimate ; and I was desirous, if possible, to use it in a more concentrated form, so that it might be employed in a less bulky fashion. Accordingly, I prepared a gauze containing, instead of one-half per cent., one per cent. of the sublimate.

The first case in which I used it was that of an elderly lady, from whom I removed the mamma and cleared out the axillary glands. I put immediately over the wound a piece of prepared oiled silk, which I dipped in a 1 to 500 solution of corrosive sublimate ; then, over this, sublimate gauze, and outside all an abundant eucalyptus dressing. On the following day, when we changed the dressing, I found that, under the oiled silk, exactly corresponding to its extent, the skin was highly irritated, and was covered with small vesicles. I also found that the inner side of the arm, where there was no wound, was in the same state of intense irritation. I covered the irritated parts of the inner side of the arm with eucalyptus gauze, dipped in a weak solution of carbolic acid, and I applied to the wound the 1 per cent. sublimate gauze without any intervening protective oiled silk. On the following day, I found that the little vesicular pustules, which had formed the first day under the protective, had healed, and that the inner side of the arm also had recovered from its irritation. How were these facts to be explained ? I believe the explanation to be this. The 1 to 500 watery solution of corrosive sublimate, prevented by the oiled silk from escaping,

had acted as a powerful irritant upon the skin ; but when the 1 per cent. gauze was applied directly to the wound, the oozing of albuminous discharge from the pustules and from the edges of the wound mitigated the action of the corrosive sublimate, and so prevented further irritation there. Again, in the case of the arm, what had occurred was, free perspiration had taken place, and the perspiration forming, with the corrosive sublimate in the gauze, a watery solution, had produced irritation where the perspiration was, on the same principle as the watery solution had caused irritation under the protective.

I continued to use a corrosive sublimate dressing in this case. It so happened that there was a very free haemorrhage after the operation. I never before saw small vessels so atheromatous. We had to tie multitudes of little rigid arteries, and, in spite of this, a considerable effusion of blood took place, and bagged under the skin. She left town with the outer angle of the wound still unhealed, and having the remains of the blood-clot exposed in it—the dressing employed being a piece of absorbent cotton-wool charged with about five per cent. of sublimate, secured in its place with collodion—and she came every few days to London to have the dressing changed. On these occasions I found that, although the serous discharge had soaked the wool more or less, there was no irritation caused by it ; and the blood-clot, in course of time, presented an appearance which I never happen to have seen before. From the epidermic edges of the little wound, the epidermis crept over the surface of the blood-clot like the white claws of an animal, extending over the dark coagulum. We are familiar with the organization of the coagulum in exposed wounds, and we are also familiar with the fact that in the course of time the superficial clot may be removed, and a scar found under it, without any suppuration having taken place, or any granulation, strictly speaking ; but I never happened to have seen before this formation of epidermis extending over the surface of an exposed coagulum ; and the explanation I believe to be that, while the sublimate wool rendered the wound, for surgical purposes, perfectly aseptic, the albuminous discharge from the wound prevented the sublimate from coming into operation as an irritant, and so we had, in a peculiarly perfect manner, complied with the essential conditions for the treatment of superficial sores—namely, the exclusion on the one hand of septic agency, and on the other of the irritating property of our dressing. I may add that the wound healed without a particle of pus having been formed from first to last.

While this case showed that in the sublimate we had an agent that might give very beautiful results, it also indicated that we were dealing with an edged tool, which, while it might do admirable work, was very apt also to cut our fingers ; and the question suggested itself, Was it, after all, possible to use

corrosive sublimate in such a way as to get the advantages without the disadvantages ? The question, for instance, suggested itself, Suppose the discharge had been more considerable in this case, so as to soak thoroughly through and through the dressings, what might then have been the result ? What is the action of the albumen of serum or blood upon corrosive sublimate ? How do they act upon each other ? It is, I believe, a very general view in the profession, not to say among professed chemists, that albumen forms, with corrosive sublimate, an insoluble, or very sparingly soluble, albuminate ; and that this albuminate is inert ; whence the efficacy of white of egg as an antidote in corrosive sublimate poisoning. In the fourth edition of Miller's *Chemistry*, it is distinctly stated that an albuminate of mercury is formed as a precipitate when a solution of albumen is treated with corrosive sublimate. In the third appendix to Watts's *Dictionary of Chemistry*, the albuminates are still spoken of, and, in the intermediate appendices, there is nothing said to modify the view expressed in the original work, viz. ' Mercuric albuminate is a white substance obtained by precipitating corrosive sublimate with albuminate of sodium (white of egg) '. If it were really true that the albumen acting in a certain proportion on the corrosive sublimate would form with it an absolutely inactive compound, this would be a very serious consideration for the use of corrosive sublimate in surgical practice. The albuminous (proteid) constituents of the blood are enormously abundant ; while the quantity of corrosive sublimate we can use in our dressings cannot be very great. According to the most recent views regarding albumen, its chemical equivalent is about six times that of corrosive sublimate ; but the quantity of albuminous material in the serum of the blood is very much more than this in proportion to the sublimate we could think of employing. My first experiment upon this matter was as follows : I made a solution of albumen from white of egg, and then introduced it into some sublimate-wool, the quantity of albumen used being double that which would be requisite to neutralize the corrosive sublimate, according to the view to which I have referred. After leaving the albuminous fluid in the wool for a certain time, I squeezed the wool, and obtained a clear fluid, and I was surprised to find that this clear fluid tasted strongly of corrosive sublimate—an albuminous fluid, containing twice the quantity of albumen that was essential, according to the views to which I have referred, for neutralizing the corrosive sublimate, had picked up from the wool corrosive sublimate enough to give the fluid that came out a strong taste of that substance. I mixed this liquid with an equal part of milk obtained from a dairy, and the milk remained perfectly free from souring, showing that the albuminous fluid which had come through the wool had antiseptic qualities, as well as the taste of corrosive sublimate.

I afterwards made other experiments with blood itself, and that to which I will now refer was with the serum of horse's blood. My first attempt to obtain serum from horse's blood failed. I wished to get the blood in an aseptic state, so far as one conveniently could without going too much into detail; and I used a glass jar which I had had by me for a long time past, and which had been used for experiments with regard to catgut, and had certain impurities adhering to it which could not be cleaned off. I purified this with a 1 to 500 solution of corrosive sublimate, and then introduced into a horse's jugular vein a glass tube purified in the same way, and through this tube drew blood into the jar, and allowed it to coagulate, intending to use the serum which should ooze out of the clot as it contracted. I was baffled, however, by finding myself again in presence of a fact which I described some years ago, where antiseptic precautions had been used in obtaining blood; the clot never contracted.

When I first witnessed this fact, having found the novel procedure of antiseptic precautions, in taking blood, followed by the novel phenomenon of failure of the clot to contract, I was disposed to attribute the one to the other, and to imagine that the destruction of the septic organisms was, in some way or other, the cause of the absence of the shrinking. Then it was suggested to me that Liebig had shown, in his *Letters on Chemistry*, that, if glasses are heated, they lose, for a time, their usual property of causing certain phenomena of crystallization; and, as my glasses had been always purified by heat, there might be some peculiar physical property in the glass to account for the circumstance. But here we find the same phenomenon cropping up, although the glass had not been purified by heat, and although it had not even a clean smooth surface.

It may be interesting to you to observe that, though the antiseptic precautions used were but of a rough kind, still no genuine putrefaction has occurred, in spite of the hot weather, in this blood taken on the 9th of September. But the remarkable fact to which I wish to direct your attention is that, while the buffy coat peculiar to horse's blood can still be recognised, it has entirely failed to contract, and is to be seen adhering to the surface of the vessel. I must confess it seems to me barely conceivable that the development of organisms can be the cause of the contraction of the clot under ordinary circumstances, considering how soon that contraction begins to come into play. Yet to what else are we to attribute it? It is to me, I confess, a perfect mystery. At the same time, to us surgeons it must be admitted to be highly interesting, because in antiseptic surgery, at all events, this is the very condition of things in which we find the clot. We do not find a clot shrink away, or tend to do so, from the sides of the wound, but it retains its original bulk until it is gradually diminished by absorption and organization; and if a clot forms in the vicinity of a ligature

upon a large artery, it seems very important that it should not shrink away from the sides of the vessel, but remain there, in its original dimensions, to serve its purpose of a plug.

On the same occasion on which I obtained this blood, I received a portion into another vessel, and stirred it during coagulation to remove the fibrine. This whipped blood answered my purpose perfectly, because, by virtue of the remarkable tendency that the red corpuscles of the horse's blood have to aggregate into dense masses, and so fall rapidly in the course of a short time, the mixture of serum and red corpuscles was found, in three hours, to consist of about one-half corpuscles and one-half serum, and therefore I could use the serum for the purpose of my experiment.

The experiment was performed in the following manner. A glass tube, such as this (three-quarters of an inch in calibre and three inches in length), open at each end, was packed with a certain weight of antiseptic dressing to be tested, say sublimate-wool, occupying about two inches of the tube; then a weighed quantity of serum, just enough to soak the wool, was poured in at one end of the tube held vertically; it was then left for about half-an-hour in a warm box at the temperature of the body, after being put into a stoppered bottle, to prevent evaporation; then the serum and the sublimate in the dressing having been allowed to act upon each other for about half an hour, a little more serum was poured in, the tube being in the same position as before. The result was that a certain quantity flowed out below, and was received into a test-tube. The lower part of the wool and the serum in the test-tube were next inoculated with putrid blood, diluted with ten parts of water, to prevent the smell being so great as to make one think that putrefaction existed when none had occurred, a tenth of a minim being applied by means of a suitable apparatus. Lastly, the wool-tube in its stoppered bottle, and the test-tube with a cap of thin macintosh tied over its mouth, were replaced in the warm box. The object of this was to ascertain whether the dressing, after having been thoroughly soaked through and through with serum, would resist a potent septic inoculation; and also whether the fluid that had come through the dressing was itself an antiseptic fluid. If such should prove to be the case, we should have all the requisites we could desire for an antiseptic dressing. It was a very severe test, for it is comparatively rarely that we have such intensely putrefying substances applied to the surface of our surgical dressings, and it is also comparatively rarely that the dressings are soaked so very thoroughly with blood or serum.

I used three kinds of sublimate-wool, one containing 1 per cent.—twice as much as there is in the wood-wool—one 5 per cent., and the other 10 per cent. I have mentioned that it was on the 9th of September that this was done, and

all these three wools remain perfectly pure, so far as the sense of smell can detect, to the present time. The bottles are before you, and even in that containing the 1 per cent. wool, you will find nothing but a smell, something between that of mortar and the inner bark of some trees, which is the immediate effect of the action of corrosive sublimate upon the serum. The serum that had come through the dressing equally resisted the inoculation. By means of a process of testing with which I will not now trouble the Society, I could ascertain pretty exactly the proportion of corrosive sublimate present in these liquids that had thus come through. The corrosive sublimate made the liquids turbid in the case of the wool with stronger proportions ; but, in the case of the 1 per cent., it had not rendered the serum turbid, and therefore I was able, without the use of the microscope, to judge by the existing transparency, and also by the presence or absence of scum on the surface, whether any organisms did or did not develop ; and none whatever occurred. As regards the strongest wool, the liquid which came through contained about one part of corrosive sublimate to 160 parts of the fluid. I tasted this, and found it had the peculiar metallic nauseous taste of corrosive sublimate. I also mixed some of it with five parts of milk got from a dairy, and therefore, as we know, containing bacteria of various kinds. Here is the milk, still fluid after the lapse of nearly six weeks, although, when it was mixed with the serum, it was already advancing towards septic changes. The first of those changes, namely, lactic fermentation, has been prevented, otherwise the milk would not have been fluid, as you see it to be. There is not the slightest smell either of the lactic or butyric fermentation, but only that which Pasteur pointed out to occur as the result of oxidation of the fatty matter of milk—a little odour of suet. That is exactly the smell that you have in boiled milk kept for a few weeks in an aseptic state.

Thus, Mr. President, we had evidence that corrosive sublimate forms, with the serum of the blood, a material, whether we call it a chemical compound or not, which retains the properties of the corrosive sublimate, both as to taste and as to antiseptic virtue. Now it seems to me highly unlikely that both the characteristic taste of corrosive sublimate and the antiseptic virtue would be retained if the corrosive sublimate were decomposed in any way ; and therefore, I venture to think, speaking with all deference to chemists, that we have not here a chemical combination in the ordinary sense, but an association of particles, such as occurs in solution : not an albuminate of mercury, but an albuminate of sublimate, if I may use such an expression ; a loose association of particles of chloride of mercury with albumen. If such be the case, I need hardly point out how important this may be with reference to the surgical uses of corrosive sublimate. The discharges, in passing through a sublimate dressing, may acquire

from that dressing chloride of mercury, still in solution, though associated with albumen, and still retaining antiseptic properties.

I may conclude this matter of the relations of the blood-serum to corrosive sublimate by showing some illustrative specimens. I found that, if serum is mixed in small proportions with corrosive sublimate, in a mortar, the result is the production of a thick, opaque, slimy material; but if you add a little more, and still a little more, you get this material redissolved in the serum, until, if you use as much as 150 parts of serum to one of sublimate, you get a clear solution. This test-tube contains serum from the blood of a horse, mixed with one two-hundredth part of corrosive sublimate. You will see that there is no precipitate here at all. This other test-tube contains the same amount of corrosive sublimate (1 to 200); but the liquid mixed with it, instead of being serum simply, is serum with an equal part of distilled water; and here we have what the chemists describe as a precipitation of the albumen, the upper part of the liquid being clear. Now, this upper part of the liquid contains exceedingly little corrosive sublimate; it has almost all gone down with the albumen; but if we take some of this precipitate itself and mix it with more serum, it will be redissolved by that serum. This afternoon, I mixed some of this precipitate with some serum already containing one four-hundredth part of sublimate, and the result has been the clear solution that you see here. This albuminate, if we are to call it so, is therefore highly soluble in blood-serum, and that is one important point to which I wish to direct attention.

While the sublimate is thus, so to speak, intact when associated with albumen, it is rendered very much milder in its action. I took some of the serum which had come through the 10 per cent. wool, containing one part of corrosive sublimate to 160 parts liquid, soaked a piece of lint with it, and applied it to my arm, put over this a piece of thin macintosh cloth, to prevent evaporation, and secured this with rubber adhesive plaster. I retained this dressing in position for twenty-four hours, and on its removal found an absolute absence of any irritation, although my own skin is pretty sensitive. We have seen how, in twenty-four hours, one part of sublimate to 500 of water already produced pustules; yet here one part to 160 of serum produced no irritation whatever. The association, then, of the albumen with the corrosive sublimate greatly mitigates its action, and makes it much less irritating. Thus we are able to understand how the discharges coming from a wound soaking a sublimate dressing may not cause irritation, although the dressing may contain a large proportion of corrosive sublimate. Such being the case, I hoped that we might be able to use corrosive sublimate in pretty strong proportions in a gauze for the dressing of wounds; and therefore, not very long ago, in a case of psoas

abscess, I applied gauze containing 5 per cent. of corrosive sublimate, with a little gum arabic to prevent the crystals flying off. On changing the dressing the following day, I saw in the vicinity of the wound all perfectly satisfactory; but, the discharge having gone principally backwards, I found that the further I looked towards the sacrum the more and more evidence of irritation did I find, until over the sacrum itself, beyond the edge of the dressing, there was absolutely a large vesicle. How was that to be explained? The explanation I believe to be simply this. If an albuminous discharge travels through a dressing containing corrosive sublimate only, it, in the first instance, forms, with the corrosive sublimate, a non-irritating albuminate, so to speak, but leaves more or less of its albumen behind in the form of a precipitate. As it goes further, and meets with more corrosive sublimate, it leaves more albumen behind, and so, as it advances, becomes more and more nearly a watery solution of corrosive sublimate, producing the highly irritating effects with which we are familiar. This result, I confess, made me at first despair of using corrosive sublimate in anything like a concentrated form as a surgical dressing. But it afterwards occurred to me, might it not be possible, as corrosive sublimate associated with albumen is so little irritating, to associate albumen with the corrosive sublimate in the dressing? Where should we get our albumen from? Well, we may get it from horse's blood. There are in every town horse-slaughterers. If you stir horse's blood while it is coagulating, you may get from one animal some gallons in the form of serum. There is the albumen for you, if only it can be made useful. There is a horse-slaughterer in the north of London who will let us have this serum absolutely for nothing; it is simply a useless material to him. This being so, I ascertained in what proportions the serum and the sublimate might be mixed, so as to give a workable article; and I find that you may employ them in almost any proportions. If you use a very small amount of serum, you get, indeed, a thick opaque substance; but this can be perfectly well blended with gauze or other materials. Here is a gauze which has been charged with serum containing one part of corrosive sublimate to seventy-five. Two and a half parts of the liquid are required for charging one part of the gauze; and you will see that this is not at all an unpleasantly constituted substance, physically. It is destitute of odour; you will scarcely perceive it to the taste; and you would hardly believe that it contained nearly three parts per cent. of corrosive sublimate.

The corrosive sublimate is so intimately blended with the serum that, when it dries (as seen on this plate of glass), no separation of crystals takes place. Whether we use 1 to 100, 1 to 70, 1 to 50, or even 1 to 30 parts of blood-serum, they are perfectly amalgamated, and therefore, from a gauze like that,

no corrosive sublimate can fly off. It can be manipulated as you please, and, as applied dry to the skin, it is absolutely unirritating.[1] Then, in the next place, it is unirritating as acted on by the perspiration. If water is made to act on sublimated serum dried, it does not redissolve it as serum does, but it renders the mass opaque, the water being only partly absorbed into it; and the water which remains unabsorbed contains exceedingly little of the corrosive sublimate, which is almost all retained by the albumen. Hence, when perspiration soaks into such a dressing, though it moistens it, it does not produce irritation. I made some gauze with serum so strong with corrosive sublimate as to have 1 part to 30, which implies more than 6 per cent. of corrosive sublimate in the dried gauze. I moistened a piece of this with distilled water, and fixed it on my arm for six hours in the manner above described; and, when I removed it, I found the skin free from irritation. Thus, you will observe that, by associating albumen with the corrosive sublimate, we seem to be able to get rid of its irritating properties.

But the important question arises, Does corrosive sublimate, when thus associated with albumen, retain sufficient antiseptic virtue for surgical purposes? The method of experimenting which I have described is adapted for testing the efficacy of any antiseptic dressing, and I have used it for various others besides sublimated ones. I have employed it for salicylic cotton-wool, for iodoform cotton-wool, for eucalyptus gauze, and for carbolic gauze. I have mentioned that the test is an exceedingly severe one, and I find that, after the lapse of a few weeks, salicylic wool soaked with serum and inoculated as above described, stinks; and the same is the case with iodoform wool. The eucalyptus gauze, however, if freshly prepared, remains pure; as also does carbolic gauze. We have seen that the 1 per cent. sublimate-wool resisted, still more the 5 per cent. and the 10 per cent. In accordance, therefore, with our previous experiments with iodoform and salicylic acid, they did not stand the test as well as carbolic acid, or eucalyptus, or the corrosive sublimate. But we get a different result if, instead of using serum of blood, we use serum mixed with blood-corpuscles, such as we readily get from the cow, in which the corpuscles do not aggregate so closely as in the horse, but remain suspended in the serum. I need not, of course, tell any members of this Society, that the corpuscles are enormously richer in protein substances than the serum is, so that serum and corpuscles contain about 2½ times as much of proteid material as the serum does; and as albuminous materials mitigate the action of the corrosive sublimate, they cannot fail to interfere more or less, also, with its

[1] If such a gauze be torn, it gives off a dust which irritates the nostrils. It is, therefore, better to cut it with scissors.

antiseptic action ; and when we use serum and corpuscles, instead of serum only, we find that the sublimated wood-wool (which I should have said did very well with the serum so far as the sense of smell indicates) fails completely. The 1 per cent. sublimate-wool failed also ; the 10 per cent., however, stood the test perfectly, even with blood in substance. Now, as to our gauze made with albumen associated with the sublimate, the sero-sublimate gauze. Such a gauze, prepared with 1 part of sublimate to 100 of serum, stood the test absolutely when tried with serum. It therefore proved itself superior to salicylic and to iodoform wool. But with the blood in substance, how does it behave ? The tube in this bottle contains a portion of the gauze treated with the cow's blood, serum and corpuscles, and inoculated nearly a month ago in the same potent manner to which I have referred, and you will observe that it has no putrid odour. Really, then, this sero-sublimate gauze seems to stand the test completely. I may say that, when tried with corpuscles and serum, our best eucalyptus gauze failed utterly, so that everything that I have tried failed with serum and corpuscles, except the stronger sublimate preparations and carbolic-acid gauze.

Then the question comes, how far may we go in the strength of our sublimate combined with the albumen without causing irritation ? During the last three weeks, my cases at the hospital have been dressed with this material. We have used the kind of gauze which was tested in the above experiments, made with 1 of sublimate to 100 of serum, and also one made with 1 of sublimate to 50 of serum. We find that the 1 to 50, in the majority of cases, has caused no irritation whatsoever, but in a very few it has caused some irritation, which, however, has disappeared, and the sores caused by the 1 to 50 have healed when the 1 to 100 has been substituted for it. Therefore it looks as if we were very near our limits, as if that prepared with 1 of sublimate to 100 of serum was trustworthy and unirritating, even to all skins, and that prepared with 1 to 50 was unirritating to most skins. Now there is this to be observed for our comfort, that the discharge both from wounds and from abscesses antiseptically treated is a serous discharge, not a bloody one, except in the case of wounds during the first twenty-four hours ; and even in the first twenty-four hours, except in cases in which the dressing has to be taken down for reactionary haemorrhage, the blood is always more or less diluted with serum. If, therefore, we have a dressing which has stood our severe test with serum mixed with the full amount of corpuscles, we are surely right in regarding it as trustworthy.

Last Friday, I amputated at the hip-joint in a boy twelve years of age, on account of a sarcoma of the lower half of the femur. The wound was exceedingly vascular, and there was a great deal of bloody oozing in the first twenty-four

hours, but very little blood escaped externally, because this gauze absorbs very much better than our carbolic-acid or eucalyptus gauzes do, containing as they do resin and paraffin ; and I would strongly recommend that, during the first twenty-four hours, this gauze should be used in at least sixteen layers. It is now three days since the operation was performed, and, from the perfectly normal temperature and returning appetite and strength, I think we may be satisfied that the boy is already out of risk of septic complications. And this you will observe, is a very testing case.

I may mention one other case, that of a boy six years old, from whom, nearly three weeks ago, I removed a portion of a rib, for the purpose of allowing free drainage to empyema. We let out thirty ounces of thick, odourless pus, and a great quantity came out afterwards. He has been dressed with sero-sublimate gauze ; and he is one of the instances in which gauze prepared with the 1 to 50 serum caused irritation, which disappeared under the 1 to 100.

In him we have witnessed the beautiful course which, I believe, we can only see under antiseptic treatment efficiently managed, of no more pus formed after the first pus has been evacuated—nothing but a serous oozing rapidly diminishing ; and I was delighted to see, on coming back after a fortnight's absence, how plump the emaciated little fellow had become. And the serous discharge is now so slight, that I believe it would be already safe to remove the drainage-tube. This case, I think, proves that our dressing is aseptic, that the germicidal properties of the corrosive sublimate have come into play in the preparation of the dressing, so that any injurious organisms which existed in the blood or in the gauze before they were brought into preparation, have been destroyed : because, if there had been merely the inhibitory influence of the sublimate upon the organisms, the serum pouring out from the pleura, washing away all the antiseptic in the vicinity of the wound, but leaving the organisms lodging among the fibres, then we should have had putrefaction, or other disturbing causes, showing themselves. No such thing having occurred, this case seems of itself sufficient evidence that our dressing is really a safe one in so far that it contains no living organisms of importance to start with.

I have here a sample of a very cheap fibre, sent me from the south of France, prepared with this sublimate-serum, and then teased out, showing that we may use this material for charging various fabrics. This fibre is highly absorbent ; and I may remark that, if we have a very highly absorbent dressing, we may, and must, use a larger proportion of the sublimate. A gauze will absorb only about three times its weight of liquid ; cotton-wool will absorb ten times its weight ; and therefore you observe, when the one dressing is saturated, it has three times as much of the liquid in it, and thus has the sublimate three

times as much diluted. Being so much diluted, it will be in proportion less irritating, but a stronger proportion is required to make it safe unless you use it in a very large mass. I believe the French charpie, made of old rags, or even old rags themselves, might be quite well prepared with sublimated serum. I have here some rags which have been so treated, and which are quite absorbent, and therefore the dressing promises to be a very cheap one. If the serum is treated with a certain proportion of sublimate, not sufficient to make it solid, it may be kept for any length of time. For aught I know, this sublimated serum may come to be an article of commerce, which may be used in hospitals, or even in private practice. I also think it possible that a material of this kind, dried and reduced to powder, may come to be used for the purpose of mixing with vaseline for an antiseptic ointment, or even for dusting in, under certain circumstances, among our dressings.

I regret that time has not allowed me to bring this matter more completely to an issue as regards its practical applications. At the same time, though the subject is, to a certain extent, immature, I ventured to hope that the interest of some of the points to which I have referred might justify me in bringing it before you.

AN ADDRESS ON A NEW ANTISEPTIC DRESSING

Delivered before the Medical Society of London, November 4, 1889.

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Mr. President and Gentlemen.—When I last had the honour, five years ago, of addressing this Society at the request of its President, I brought before you an attempt I had made to utilize the powerful antiseptic properties of corrosive sublimate without the great disadvantages attendant upon its highly irritating qualities.[1] I had ascertained that when corrosive sublimate precipitates albumen the precipitate is not, as had been generally supposed, an albuminate of mercury—that is to say, a combination of albumen as an acid with mercury as a base; in other words, that the albumen does not displace the chloride from its combination, but that the bichloride of mercury retains its properties intact, the albumen being loosely associated with it, in a species of solid solution, if I may so speak.

Further, I had found that this precipitate, even after drying, is capable of being dissolved in the serum of the blood, and that the solution in blood-serum is powerfully antiseptic while not irritating. I proposed and brought before you a new dressing in the shape of what was termed the sero-sublimate gauze, charged with a solution of corrosive sublimate in the serum of the blood. This gauze gave very satisfactory results, both in my own hands and in those of surgeons in places so far distant as Poland and Spain. Nevertheless, it was not all that could be desired by any means; it was somewhat harsh mechanically; it was not very absorbent (a serious defect), and one of the materials of which it was made (the serum of horse's blood) was not always easily obtainable. I was, therefore, well disposed to look for something superior.

A few weeks after that communication was made to the Society, a firm of manufacturing chemists, Messrs. Gibbs, Cuxson & Co., wrote to me saying that they had found that if chloride of ammonium or sal ammoniac in quantity equal to one-fifth part of the weight of the bichloride of mercury was added to the mixture of bichloride of mercury and blood-serum, the result was a much more fluid preparation than I had obtained. If I used a preparation of one part of bichloride of mercury to 100 of blood-serum, I got a thick liquid somewhat difficult to diffuse in gauze. They therefore suggested that by adding

[1] See p. 293 of this volume.

sal ammoniac in that proportion I should get a much more workable arrangement. On consulting chemical works I found that one-fifth of sal ammoniac was exactly sufficient to produce with bichloride of mercury the salt long known to chemists as sal alembroth, a double salt of bichloride of mercury and chloride of ammonium. I naturally wished to ascertain whether this addition of sal ammoniac would impair or even destroy the antiseptic properties of the bichloride of mercury. I therefore made experiments on the point, and I found that the sal ammoniac associated in the form of a double salt with the bichloride of mercury did not by any means impair its antiseptic properties ; on the contrary, it improved them, so far at least as concerned that which we have to deal with as surgeons, an albuminous fluid like the serum of the blood. Sal alembroth and bichloride of mercury proved to be exactly equivalent weight for weight as antiseptics in such a fluid. Each had to be used in normal serum of specific gravity of about 1,025 in the proportion of about 1–1,000th in order to prevent altogether the development of micro-organisms. Those who are acquainted with Koch's researches will consider this a very high proportion. Koch has shown that in a solution destitute of albumen 1–100,000th part of bichloride of mercury is sufficient to prevent the development of organisms ; but when we have albumen present in the solution the case becomes altogether altered. Albumen interferes with the antiseptic action of corrosive sublimate, and thus in serum of the blood of specific gravity 1,025 we require, as I have already said, as large a proportion as about 1–1,000th instead of 1–100,000th.

When the albumen is small in amount, less corrosive sublimate proves efficient. Thus, in a case of spermatocele, where the specific gravity of the fluid was exceedingly low—only 1,007—I found that 1–1,000th, just intermediate between the proportions required for blood-serum and water, was efficacious. On the other hand, when blood-corpuscles are mixed with the serum in the same amount as in the circulating blood, making the albuminoid substances much more abundant than in serum, we require proportionately more of the corrosive sublimate ; at least 1 to 500 is required for the purpose of preventing development. This is a most important consideration after an operation. In the first twenty-four hours the discharge contains a large amount of blood-corpuscles as well as the serum ; whilst, at the same time, it is the most copious—more copious than it will be in any subsequent day, provided all goes well aseptically. It is therefore, an exceedingly serious consideration that in the first twenty-four hours we have a discharge which in both these respects tests our antiseptic more severely than it will ever be tested again, both from its abundance and from its quality. Still, the sal alembroth, whether used with blood-serum or with a normal mixture of serum and corpuscles such as that obtained by

whipping the blood of the ox so as to get rid of the fibrine, proved equivalent antiseptically to bichloride of mercury.

I may perhaps say in a few words how the experiments were conducted. For the purpose of ascertaining whether a given antiseptic can or cannot prevent development of organisms, a very simple mode of experimentation suffices. What we have to do is to ascertain whether it is *inhibitory*, not whether it is *germicidal*. The only special apparatus required for such experiments is a warm chamber which can be kept pretty constantly about the temperature of the human blood. Beyond this a few stoppered bottles, with well-fitting stoppers—perhaps half-ounce stoppered bottles—are really all that is required. Into a series of such bottles serum of the blood, to the amount, say, of 150 grains, containing solutions of the antiseptic of different strengths, is introduced. These are all inoculated by means of a small syringe pipette with the same quantity, say, 1–10th of a minim, of some potently septic liquid, such as blood-serum in a state of advancing putrefaction. The bottles are placed in the incubator, and then, if development takes place, that is evidence that in the bottle in which it occurs such proportion of the antiseptic as that bottle contains is inadequate; if no development occurs, we have proof of antiseptic efficacy. The transparency of the serum permits a recognition of the development of the organisms, which invariably causes opacity. If we have no change in this respect, if the serum maintains its transparency, at the same time keeping its odour unimpaired, and, further, if microscopic examination of any little sediment there may be shows that it contains no organisms, we have clear evidence that the antiseptic in the proportion concerned has proved efficacious.

Now if the sal alembroth was equivalent to the bichloride of mercury, weight for weight, that shows that the sal alembroth was really more efficacious as regards the quantity of bichloride of mercury it contained. The bichloride of mercury having the sal alembroth added to it, and also water in the double salt that is formed, is increased in atomic weight very considerably; and therefore if an equal weight of alembroth is equivalent in antiseptic action to bichloride of mercury, that shows that the bichloride of mercury is made more efficacious in the blood-serum by the addition of the chloride of ammonium. The chloride of ammonium in combination protects the bichloride of mercury, so to speak, to a certain extent, from the interfering influence of the albumen.

At the same time, the sal alembroth proved much less irritating than bichloride of mercury. Experimenting on my own skin, I ascertained that it has certainly not half the irritating property of corrosive sublimate. The chloride of ammonium attached to the bichloride of mercury, while it protects the bichloride in some degree from the influence of albumen interfering with

its antiseptic operation, prevents it also from acting so powerfully on the human skin. And thus the union of sal ammoniac with corrosive sublimate had the double advantage of rendering it both more efficacious antiseptically and much less irritating.

Hence I was at first much pleased with sal alembroth. But it soon appeared that there were certain disadvantages attending it. These depend very much upon its excessive solubility. It is essential for a satisfactory antiseptic dressing that the antiseptic should not be readily washed out of it by the discharge. Sal alembroth is so exceedingly soluble that it is washed out with the greatest ease ; thus we were always, even if we used large masses of sal-alembroth gauze, in fear that when the discharge was copious the antiseptic would disappear, say, within the first twenty-four hours, and then the septic mischief would have an opportunity to enter. There was another disadvantage from this great solubility. When the discharge entered a mass of the sal-alembroth dressing it dissolved out the alembroth from it, passed into another part of the dressing, and there took up another portion of the sal alembroth, and so went on from part to part of the dressing, until, if the discharge was copious and the dressing large, as it must be when the discharge is copious, before the discharge got to the edge of such a dressing it became so concentrated a solution of the sal alembroth as to be highly irritating. We have seen, for instance, after the removal of the mamma, when the first dressing was changed on the following day, that there has been over the scapula and the neighbourhood a huge blister. No doubt that was only a temporary inconvenience. We never had the discharge again so great as in the first twenty-four hours, but still it was a great inconvenience.

Such being the disadvantages of sal-alembroth dressing, I was disposed to seek for something better. I may say that I myself have never published anything in favour of sal-alembroth dressings ; I have never been satisfied with them. It has leaked out that I have used them, and they have come into extensive employment, but never with my published sanction.

In the course of the following year I made various experiments in the hope of rendering sal alembroth more useful in different ways, with which I need not trouble you, but without much success. In February 1886 my attention was drawn by Mr. Martindale of New Cavendish Street, to cyanide of mercury as possibly a valuable antiseptic, and, if so, having this advantage, that it did not coagulate albumen. I therefore proceeded to make experiments with cyanide of mercury, and I found, indeed, that in inhibitory power it was remarkably efficacious. I have said that with blood-serum sal alembroth or bichloride of mercury is required in about 1–1,000th part. I found that the cyanide of

mercury kept blood-serum with only 1–10,000th part perfectly free from organic development, in spite of inoculation with potent septic fluid, for a month, when the experiment ended. I may remark that we have in the cyanide of mercury a striking instance of the discordance that there may be between inhibitory power and germicidal power in an antiseptic. In inhibitory power the cyanide of mercury is, as we have seen, exceedingly high; but in germicidal power it turns out to be very low. Mr. Cheyne has made experiments for me, which have shown that even 1–1,000th part in water is incapable of destroying the germs of bacteria. Still, the inhibitory property of cyanide of mercury was a most important point if in other respects the salt were not disadvantageous; but, unfortunately, it proved to be so highly irritating that the greater irritating property of the cyanide of mercury more than counterbalanced its superior inhibitory power. It naturally occurred to me that the cyanide of mercury might perhaps combine with some other cyanide and form a double salt, having advantages corresponding with those presented by sal alembroth as compared with bichloride of mercury. I tried the soluble double cyanide of mercury and potassium, but found it quite too irritating. I here again consulted Mr. Martindale, and he mentioned to me that in Watts's *Dictionary of Chemistry* it is stated that a double cyanide of mercury and zinc of very slight solubility may be formed by mixing together a solution of the double cyanide of mercury and potassium with a soluble salt of zinc, the zinc taking the place of potassium. I therefore obtained some of this material, and proceeded to make experiments on it. I found, in the first place, that it was quite insoluble in water. This seemed at first extremely unpromising. It was soluble in about 150 parts of glycerine, but insoluble in water. I found, however, that it was soluble in about 3,000 parts of blood-serum, and therefore it was possible that it might work antiseptically. I made experiments to ascertain whether such was the case or not, and I found that this zinco-cyanide of mercury, as we may call it, had really most important antiseptic properties; that in the proportion of 1–5,000th part it kept blood-serum perfectly free from the development of organisms for eighteen days, in spite of potent septic inoculation.

I then tried experiments with serum and blood-corpuscles as presented in the whipped blood of the ox. On instituting comparative experiments between sal alembroth, cyanide of mercury, and this double cyanide, I found that with the alembroth all proportions lower than 1–400th putrefied within twenty-four hours after septic inoculation, while with the cyanide of mercury 1–800th part sufficed to preserve the serum and corpuscles from putrefaction. At the same time, with the double cyanide I was much surprised and much pleased to find that 1–1,200th, half as little again, was sufficient to keep the mixture of serum

and corpuscles permanently free from putrefaction. It may be said that the absence of putrefactive odour is but a rude test. There may be organisms developed without any putrefactive odour being present; that is perfectly true. At the same time, if in a given experiment we find that with one agent putrefaction occurs within twenty-four hours with 1–400th part, while with another salt there is no putrefactive odour after the lapse of weeks with 1–1,200th part, we have pretty conclusive evidence that, so far as the mixture of corpuscles and serum is concerned, you have a more efficacious antiseptic in the latter. I therefore proceeded to prepare dressings of this new substance, diffusing it—for it is an exceedingly fine powder—in water with a little glycerine added to fix it, to prevent it from dusting out. If you simply diffuse it in water, and pass gauze through it, with nothing more than the water, the result is that you have gauze which, with the slightest touch, gives out the double cyanide in a cloud of dust, which produces not only inefficacy of your dressing by loss of the proper proportion of the substance, but becomes in the highest degree irritating to the nostrils of those who are near. A little glycerine, however, prevented the double cyanide from thus dusting out. I proceeded to try it in practice. I confess I did not dare to use it—considering its very slight solubility in serum—unmixed, and I associated with it some of the very soluble cyanide of mercury; and with this cyanide gauze we tried various experiments in the way of dressing, and got some admirable results. But then, on the other hand, there were disappointments. We found, for one thing, now and then very troublesome pustules as the result of a peculiar kind of irritation. Another disadvantage was that occasionally we got suppurations, coming on at a late period in the case, such as we had never been accustomed to with our carbolic dressings. A case might go on perfectly well for, say, ten days, and then suppuration might occur about a stitch track and spread perhaps further; and sometimes the healing of cases was greatly protracted by this late suppuration. In consequence of these two circumstances I gave up the use for the time being of this material.

I then directed my attention to biniodide of mercury, which has been highly spoken of for its antiseptic powers, and which has the advantage over alembroth of being comparatively little soluble either in water or in serum. I found that the iodide-of-mercury gauze answered our purpose very well so far as its antiseptic properties were concerned, but that it had the great disadvantage of producing irritation, which it was extremely difficult to control. In order to control it, we interposed between the iodide-of-mercury gauze and the skin unprepared gauze, except in so far as it was steeped in a weak solution of bichloride of mercury (1 to 4,000). But we found that different skins differed

greatly in liability to this irritation. The iodide of mercury, which is so very slightly soluble, as you know, in water, is much more soluble in serum, and the solution in blood-serum becomes irritating. In consequence of this, we had the same disadvantages from irritation as we had with the alembroth ; and although, as in the case of the alembroth, this was only a transient inconvenience, I became dissatisfied with the iodide-of-mercury gauze. There was, however, one point of considerable interest, both theoretically and (as it turned out afterwards) practically, which we found in this investigation with the iodide of mercury. If we simply charged with iodide of mercury, say, from a solution in spirit of wine, and then applied the gauze so prepared, we found that the particles of iodide of mercury tended to gravitate down towards the skin, and there produce the most fearful irritation. It was absolutely necessary that it should be fixed. I tried various means, and among the rest a solution of starch, and then there came out this remarkable fact, that if a solution of starch is used with one of the ingredients employed for forming the biniodide of mercury by mixing a solution of iodide of potassium with solution of bichloride of mercury—if you dissolve the iodide of potassium in a weak solution of starch —the iodide of mercury thus formed in the nascent state associates itself with the starch particles in the most intimate manner, and the starch becomes entirely precipitated along with the iodide of mercury. If you take a drop of the red fluid formed by mixing these two solutions, and place it on a piece of calico, the watery material is absorbed by the calico and passes into the surrounding parts without colouring them, while the red spot with its insoluble iodide remains. If now you take a little iodine water, and apply it to the part of the calico moistened by the fluid that has exuded, you find that the iodine water produces no blue colour of iodide of starch, showing that there is no starch in the fluid that thus oozes out and leaves the iodide of mercury behind ; whereas, if you take a solution of starch and apply it as such to a piece of fabric, as far as the fabric becomes moistened so far do you get a blue colour with the iodine. Here we have, as it seems to me, a somewhat analogous case to the so-called albuminate of mercury. We have the starch particles associated with the particles of iodide of mercury ; the starch remains as such, the iodide of mercury remains as such, still they are attached to each other. And so the result was that when such a red solution produced by these two liquids was used for charging a gauze, the iodide of mercury was stuck to the gauze by means of the starch, and we had a most satisfactory arrangement in that respect. The iodide of mercury could not be washed out by water, nor did it in the least dust out. The value of this observation with reference to our present subject will appear shortly.

Being dissatisfied with the iodide of mercury, I turned my attention again

to the double cyanide of mercury and zinc. Looking back to my notes, I found such evidence of its superior antiseptic properties that I felt that we had deserted this material too readily. In the interval we had had other experience of importance with the alembroth gauze. Occasional late suppurations had at first occurred under its use, just as was the case with the double-cyanide gauze. These, however, had ceased to trouble us after my attention had been directed to the expediency of always using mercurial dressings in a moist condition. If they are used dry, the mercurial salt having no volatility, and having no power, therefore, of destroying any micro-organism in contact with it, whether derived from the manufactory or elsewhere, there could be no security that the dressing when applied was free from living organisms. This important object could, however, be infallibly attained if the dressing were used moist with an efficient germicidal solution. I put this idea into practice, and during the two years that have since elapsed we have never on any single occasion had to complain of these late suppurations. Might not the same immunity attend our cyanide gauze if we adopted with it the same expedient ?

The other objection to this double-cyanide gauze had been the irritation which it occasioned. Might not this have been due to the simple cyanide, which, as I have said, I used along with the double cyanide ? The simple cyanide is highly irritating, and just as with the sal alembroth, being freely soluble, it can be taken up by successive portions of discharge, and, when the discharge is free, may come to be in so strong a solution as to irritate. On the other hand, experiments on my own person had shown that the powder of the double cyanide might be kept applied to the skin for an indefinite time, whether moistened with water or with blood, without occasioning any irritation whatever. If this was really the explanation, and if, as our experiments seemed to indicate, the double cyanide could be trusted of itself, we might easily get rid of all irritation by using a double-cyanide dressing moistened with a weak solution of bichloride, say, 1 to 4,000, which, while it is securely germicidal, can never irritate. But here arose a new difficulty. I have told you that when we tried this double cyanide in a gauze at first, in order to prevent the dusting out, with its great inconveniences, we used glycerine ; but if we were to moisten the gauze with 1 to 4,000 solution of corrosive sublimate, we should run great risk of washing out the glycerine, and then the double cyanide would be free to dust out on drying. And, besides that, it must be admitted that the glycerine arrangement was not a good one, independently of that consideration, inasmuch as when the discharges flowed into the gauze they would wash away the glycerine, and then the double cyanide might be washed out also, and so fail in one of the most important requisites of an efficient antiseptic dressing—the storage of the

antiseptic in the dressing in spite of the discharge. How was this difficulty to be overcome?

Now came to our aid our experience with the iodide of mercury and the starch. Might it be that the particles of the double cyanide would attract starch as those of the iodide had done? It did not seem very likely, seeing that cyanogen is not known to have the special affinity for starch that iodine has. Still, I thought I would try the experiment. I prepared the double cyanide by mixing a solution of the double cyanide of mercury and potassium with a solution of sulphate of zinc. I tried this with one of the ingredients dissolved in a starchy solution, and, to my great satisfaction, I found that the precipitated double cyanide left a supernatant liquor almost absolutely free from starch, and that the particles which thus fell, the double cyanide with the starch associated, fixed themselves to a gauze in such a way that it did not in the least dust when dry. Not only so, but immediately after being charged with the precipitate diffused in water it might be washed in the wet state without the double cyanide being washed out of it, so closely did the starchy particles stick the double cyanide to the fabric. It is of great importance that in some way or other the double cyanide should be washed, because at the same time that an insoluble double cyanide is formed there are produced other double cyanides which are soluble, and which are in the highest degree irritating; they must be washed out.

Well, I thought I had thus attained my object, and that by mixing starch with one of the two solutions necessary for forming this double cyanide and allowing the precipitate to deposit itself, then pouring in more water, and, after precipitation, decanting and repeating the process another time, so as to get rid of all the irritating soluble salts, and then diffusing the precipitate through a gauze, I should have all that I desired. But when I tried to get this done by a manufacturer I found that I got blundering after blundering in such a way as to make the thing practically hopeless. There was nothing for it but in some way or other to get the double cyanide from the chemist as a definite article, and then in some way devise a means of fixing that powder of the double cyanide to the fabric. I therefore naturally tried whether a solution of starch would answer this purpose, whether the starchy particles would associate themselves with the double-cyanide particles, not only in the nascent state, which we had before tried, but also when the already formed double cyanide was mixed with the starchy solution. I found that it did so; that when a starchy solution was stirred up with the double cyanide in the proportion of one part of starch to two of cyanide, the starch was almost all precipitated, and the precipitate so formed adhered to the gauze in the most satisfactory manner.

But, though its adhesion was satisfactory enough, it turned out that the precipitate thus formed aggregated into a tenacious mass, which could not be diffused uniformly through the gauze, and here I was again at fault. This difficulty was overcome by first charging the gauze with the double-cyanide powder diffused in water, and then transferring it to a starchy bath. This at once fixed the cyanide in the gauze ; and, whereas, before it was placed in the starchy bath, the slightest squeeze made a milky fluid exude, no sooner had it been well penetrated by the starchy liquid than you might squeeze it as you pleased, and nothing came out but a clear fluid. I was much pleased with this, and it is in this way that I have prepared the gauze that I have used for the last twelve months, both in the hospital and in private practice. Still, this method had its disadvantages. When the gauze had been passed through the fluid in which the double cyanide had been diffused without any starch, it required very tender handling. If you gave it a squeeze, out came a quantity of double cyanide ; and it was plain that, although one might do it oneself satisfactorily, if we trusted to the manufacturers there would be an utter uncertainty as to what quantity of material might ultimately remain in the gauze.

Only lately has this difficulty been surmounted. It occurred to me that perhaps if the starch were first blended with the double cyanide and then dried and reduced to powder, if water were afterwards added to this dried dissolved starch associated with the cyanide, there might not be the same tendency to lumpiness and difficulty of diffusion. I found that the process did not answer quite as I hoped in the first instance, in this respect ; that the dried starch and double cyanide were extremely difficult to scrape off from any plate on which they were put to dry, and also very difficult to pound up and to diffuse for charging the gauze. But I got rid of these inconveniences by means of sulphate of potash, used for the same reason as in the preparation of Dover's powder—viz. that it is an inert substance, but with sharp, gritty particles. Mixing a pretty strong solution of starch with the double-cyanide powder, and adding to this a quantity of pounded sulphate of potash, the result is that you get a material which, after drying, is easily scraped off by the manufacturer, and easily reduced by him to an impalpable powder, which is then readily diffused in water, and makes a perfectly uniform gauze ; being mixed in large quantity with water in order to charge the gauze, the sulphate of potash is practically got rid of, and if any of it remains it does no harm, because it is inert. Thus we have the means of easily charging fabrics with this double cyanide.

I have spoken of diffusing this preparation in water, but in reality we employ for this purpose the 1 to 4,000 solution of bichloride of mercury, which fortunately does not in any way interfere with the process. I may remark

that the double cyanide, like the simple cyanide of mercury, though very efficient as an inhibitor, cannot be trusted as a germicide. There are different ways in which absorbent gauze such as this may be charged. One is to pass it folded in about sixteen layers through a trough, such as the one before me, which I have myself used, having a bar near the bottom to ensure the gauze being kept well under the liquid. It is then, as soon as you please, squeezed to press out superfluous liquid, and then, if wanted for immediate use, a simple way is to place the masses of gauze—say, six-yard pieces—in a folded sheet, turn the folded sheet over them, and roll it up. The folded sheet then absorbs the still redundant liquid, and you have moist gauze ready for use in five minutes. For the use of the ordinary surgeon it will probably be best to have the gauze dried, on the understanding that it is again moistened with 1 to 4,000 sublimate solution before being used. Here is a sample of the gauze in the dry state, which, you see, does not give off dust even when freely handled.

Other articles may be charged as well as gauze with this substance. The double cyanide being perfectly unirritating in its own substance, there is no objection to having an excess of it. If you take, therefore, some of the preparation and stir it up with 1 to 4,000 sublimate lotion, so as to produce an opaque liquid, and put linen rags into it, and then place them in a folded towel to take out the excess of liquid, you have your dressing ready prepared then and there. It can thus be very easily worked on an emergency.

We have seen that the double cyanide requires about 3,000 parts of blood serum to dissolve it. If, therefore, it is present in a gauze in the proportion of about 3 per cent., you will easily understand that blood-serum may soak through such a gauze time after time without washing the ingredient all out; so that it is a material which is admirably stored up in the dressing. That is one of its three great advantages, the others being that, while trustworthy as an antiseptic, it is completely unirritating. In actual practice the few layers placed next to the wound are washed in a solution of carbolic acid 1 to 20; this washes out the corrosive sublimate, which, though present in small amount, might irritate the wound to some extent. The carbolic acid soon flies off, and there is left in the application next the wound merely the unirritating double cyanide, and under this we find that not only do wounds, the edges of which are brought accurately together, unite beautifully by first intention, but even granulating sores heal by the gradual process of cicatrization from the edges—heal by scabbing in a way that we have never seen so satisfactory under any other dressing.

Having satisfied myself that this was really a useful material, I proceeded to request a manufacturing chemist to provide it for me on a large scale. Messrs.

Morson & Son, of Southampton Row, kindly undertook to do this, and I have to thank them for the great pains they have taken in carrying out experiments on this subject at my suggestion. Their manager, Mr. Taubman, soon informed me that in his opinion there was exceedingly little mercury in this so-called double cyanide of mercury and zinc. Very little mercury could be got from it on testing in comparison with what would be obtained if it were a true double salt. He asked if I was sure that the cyanide of zinc was not, after all, the thing that was efficacious! Was the idea of the double cyanide altogether a delusion? I need not say how much pleased I should have been if such had been the case—if we could have had the cyanide of zinc without any poisonous mercury in it as an antiseptic. The cyanide of zinc was a perfectly definite compound, there could be no mistake about it. I proceeded to make experiments, and I found, indeed, that cyanide of zinc had antiseptic properties. I made, for instance, experiments of this kind: I took a piece of glass tube like that which I hold in my hand, and packed it in two inches of its length with a piece of gauze charged with cyanide of zinc only, and then, holding it vertically, poured serum of horse's blood into it till the gauze was fully moistened; and then poured more in, till a quantity dropped out from the lower end equal to that which had produced saturation, the upper part of the gauze being thus thoroughly washed with the serum.

I then inoculated the top of the gauze with a potent septic drop. I had another such tube packed with gauze that had no cyanide of zinc in it, and I inoculated that in the same way after pouring serum upon it. I then put each into a well-fitting stoppered bottle, so as to prevent any evaporation, and placed them in the incubator. At the end of four days I opened the two bottles. That which contained the gauze without the cyanide of zinc stank, and, on taking portions of the gauze from either one end or the other, squeezing them and examining under the microscope the fluid that escaped, there were seen teeming multitudes of bacteria of various sorts. The bottle with the cyanide-of-zinc gauze, on the other hand, had a pure odour of hydrocyanic acid, which this gauze always has when moist. I then examined drops squeezed from both ends, and I found no bacteria in the clear serum that was pressed out, not only from the lower end, but even from the upper end, in the immediate vicinity of the inoculating drop, and where the gauze had been drenched repeatedly with the serum.

Now that, so far, is a result that no other antiseptic had ever given me. Take iodide of mercury, for example. Comparatively insoluble as it is, if you pour blood-serum upon it in such profusion you wash the iodide of mercury out, and if you inoculate septically the part so washed you induce bacteric

development. The test applied was, of course, an extremely severe one. In actual surgical practice the discharge which pours into the dressing is pure to begin with, supposing the wound to be aseptic at the outset. The septic agency only acts from without where the dressing has not been washed by the discharge, and in a far milder form than here, where a potent septic drop was used. Thus we had clear evidence that the cyanide of zinc really is an antiseptic. On the other hand, it turned out to be not so powerful antiseptically as our double cyanide so called. In order to compare the two salts I made another experiment similar to that last described. I packed three pieces of glass tube with gauze in two inches of their length, one of the gauzes being charged with cyanide of zinc and another with the so-called double cyanide (neither of these gauzes having been treated with solution of bichloride of mercury), while the third gauze was unprepared. Serum of horse's blood was poured into the upper end of each vertically held tube till it thoroughly soaked the mass of gauze, after which each gauze was inoculated septically at the centre of its upper end. The tubes were then placed vertically in stoppered bottles in the incubator. It happened that in the septic liquid used for the inoculation that I used there was, among other organisms, a species of streptococcus which had a remarkable power of producing an acid fermentation in blood-serum. After four days I proceeded to examine the contents of the three tubes. In the unprepared gauze there was utter putrefaction. In the gauze prepared with cyanide of zinc only, no putrefaction had taken place, but acid fermentation had occurred: both at the upper and lower end of the gauze litmus paper was reddened on application to the serum. In the putrid gauze turmeric paper was most intensely reddened, much more so than by normal blood-serum, an alkaline fermentation having occurred there. On the other hand, with the gauze that contained the double cyanide, with mercury as well as zinc, both at the upper and lower end the turmeric paper was reddened exactly as it was by the normal blood-serum. This state of things continued the next day; but on the following day, six days after the commencement of the experiment, I found that at the upper end, in the vicinity of the inoculated spot, this double-cyanide gauze purpled litmus, while at the lower end it still reddened turmeric. At the end of seven days the same condition persisted. After eight days, however, both the upper and lower end of the gauze purpled litmus. This peculiar septic organism, with the power of producing acid fermentation in serum, had gradually worked its way, in spite even of the cyanide of zinc and mercury; but the cyanide of zinc and mercury, you observe, had been much more efficacious than the cyanide of zinc alone. The cyanide of zinc had prevented the development of organisms that produced putrefaction, and only permitted the

development of the coccus that produced acid fermentation. Cyanide of zinc and mercury had for several days prevented all development. This was proof, therefore, that the mercurial element in our compound was valuable, and that we could not dispense with it.

It may be thought an unsatisfactory thing that there should have been any organism able to work its way thus through a gauze charged with our antiseptic. But I may remark, in the first place, that, as above stated, we tested the material exceedingly severely ; in the second place, that it was a long while before the organism penetrated the gauze even for a short distance ; and, in the third place, that penetration of micro-organisms through such a dressing into wounds does not seem to occur in practice, seeing that in the year during which I have used this antiseptic in my surgical work at King's College Hospital we have had no single instance in which we have had any reason to suspect septic change in the deeper parts of our dressing ; we have had no instance in which deep-seated suppuration has occurred in an operation-wound made through unbroken integument. If we have had any pus at all in such cases, it has been from the surfaces exposed between stitches or at situations where drainage-tubes have been inserted, where what I have termed antiseptic suppuration has occasionally shown itself, and even this in very slight degree. Such being the case, I feel not only permitted, but bound to bring this material under the notice of my professional brethren.

As to the composition of this so-called double salt, it is for the present uncertain. This much is already established : that the cyanide of mercury is in very much smaller proportion to the cyanide of zinc than Watts's *Dictionary* would lead us to expect from a true double salt. But what the precise composition of the salt is we do not yet know. I am having it investigated by the Pharmaceutical Society, who have kindly undertaken the work.

There is another use for this material besides the charging of dressings. The powder moistened with a weak solution of corrosive sublimate may be rubbed into hairy parts, when it will convert the hairs into an antiseptic dressing. Not long ago a medical friend of mine brought his wife to me with no less than seven sebaceous cysts in the scalp, requesting me to remove them. Having washed the hair with 1 to 20 carbolic-acid solution, I simply passed a comb over each tumour in the line where I was about to transfix without shaving at all ; and, after taking out the cysts, rubbed in some of the moistened powder into the hair in the vicinity. I then applied a dressing of cyanide gauze, and I was glad to learn that all the seven wounds had healed without disturbance.

We have now in the hospital a case of psoas abscess, shown to be of spinal origin, not only by the history of the case and the symptoms, but by the discharge

of a portion of bone with the pus. That case is pursuing a course which, allow me to say, psoas abscesses will pursue in the great majority of cases, if the surgeon uses a trustworthy antiseptic, and takes the same pains with dressing to the last as at the outset ; that is, he will find his trouble rewarded by the complete cure of these formerly incurable cases. I say this because I grieve to think that psoas and lumbar abscesses still seem to be regarded as hopeless affairs by many surgeons. In this man's case the temperature has never been affected in the least ; he has put on flesh rapidly ; the discharge, after the purulent and curdy matter that existed originally in the abscess was got rid of, has been of a serous character, and is in small and diminishing quantity. But the opening made for the discharge is in the vicinity of the pubes, and the pubic hairs used, under such circumstances, to be a constant source of anxiety to us unless frequently shaved away. Here we rub in at each dressing a little of the moistened cyanide, and convert the hairs into an antiseptic application.

I will not at present enter into the details of the preparation of this material ; these will be supplied in a note on a future occasion.

The sketch which I have given you of this investigation, though it has, I fear, wearied you, conveys but a small idea of the toil it has involved. There are those who still believe that the use of antiseptic substances in surgical practice is always useless, if not injurious. The germ theory of septic diseases is indeed now happily established incontrovertibly. All now admit that septic mischief in our wounds depends upon the development of micro-organisms in them derived from without. But the gentlemen to whom I refer are, more or less logically, disposed to trust everything to the antiseptic powers of the human tissues.

I believe I happened to be the first to direct attention to the antiseptic agency of living structures, and there is, perhaps, no one who attaches greater importance to it than I do. Without it, surgery in former days would have been absolutely impossible. Still I know too well from experience that it cannot always be trusted, and that the use of antiseptic adjuvants is in the highest degree important ; and I have the satisfaction of knowing that there is among you a constantly increasing number who, when they have operated on an unbroken skin, with a fair field around for the application of their dressings, if they see septic inflammation occurring in the wound with its attendant dangers, know that it is their fault or the fault of the antiseptic appliances at their disposal. To those among you who are impressed with this conviction I offer the dressing which I have described as the most satisfactory that I have hitherto met with ; and I venture to hope that you will regard it as a not unwelcome addition to your resources.

FURTHER OBSERVATIONS ON THE CYANIDE OF ZINC AND MERCURY

Read before the Hunterian Society, November 27, 1889.

[*Lancet*, 1890, vol. i, p. 1.]

[On the 27th of November, 1889, Sir Joseph Lister described to the Medical Society the operations he had done on two cases of long-standing dislocation of both shoulders, and in concluding made the following observations on the double cyanide of zinc and mercury.]

Mr. President, I have hitherto felt considerable hesitation in publishing cases in which the safety and success of an operation are essentially dependent upon strict antiseptic management; and my principal efforts for some years past have been directed to an endeavour to procure, if possible, greater simplicity and at the same time greater efficacy in our antiseptic methods. At a recent meeting of the Medical Society[1] I brought forward a kind of dressing which I believe will prove more satisfactory than any which has been hitherto employed. For the successful antiseptic treatment of a wound two essential points are of course necessary. In the first place, we should proceed so as to leave nothing septic in the wound before we apply the dressing, and in the second place we should put on such a dressing as we can thoroughly trust to keep out septic mischief until that dressing shall be changed. I had intended to bring before you this evening some points with regard to the former of these objects—the means by which the wound can be kept aseptic till the conclusion of the operation; but since the communication that I made to the Medical Society, I have been led to make further investigation into some matters regarding the use of the materials I then described, which seem to me of sufficient importance and interest to warrant me in taking this opportunity of bringing them before you. The material, I may remind you, is a sort of double salt, an amorphous powder, insoluble in water, composed of cyanide of mercury in combination with cyanide of zinc. It does not seem to be a true double cyanide, inasmuch as the proportion of the mercurial element is considerably less than that which should be in a true double salt; nevertheless, the mercurial element, as I have found, is of essential importance to the full antiseptic efficacy of the material. It was necessary that this powder, if introduced into a gauze or other fabric, should be fixed so as to prevent it from dusting out; for it is highly

[1] See *Lancet*, November 9, 1889 (page 309 of this volume).

irritating to the nostrils, and besides, if it dusted out, the dressing charged with it would lose more and more of its virtues. I described at the Medical Society a means by which this was prevented; how by the use of starch the powder might be fixed in any fabric which was charged with it. But I have long felt that it would be an exceedingly desirable thing if this material could in some way be coloured, because, being perfectly colourless, if a gauze is charged with it, we have to trust entirely to the manufacturer as to whether the antiseptic element is present in due proportion or is not. It would be very advantageous if it could be coloured, so that we might see by the tint where the antiseptic substance was, and whether it was uniformly distributed or otherwise. Therefore, before publishing the note which I had promised as to the preparation of the substance, I made attempts to stain this material. I tried various forms of dye, and I found that some of the aniline dyes are precipitated by this zinco-mercuric cyanide and some are not. For instance, magenta is not precipitated in the least, but methyl-aniline violet, and gentian violet, which seems to be a mere variety of the same thing—these are precipitated, and an exceedingly small amount of the dye is sufficient to give adequate colour to the double cyanide. I proceeded to charge a piece of gauze with some of this dyed cyanide, to see how it would tint it; and when it was dry I was much surprised to find that the gauze charged with the tinted cyanide did not dust in anything like the same degree as a gauze would have done which had received the untinted salt; so much so that a gauze charged with the tinted cyanide was very much on a par as to dusting with the gauze charged by means of starch.

Of course, if this were so, it would be a very satisfactory arrangement; we should dispense with the starch and also with a quantity of sulphate of potash which was used for purposes that I need not here refer to;[1] we should greatly simplify the method of manufacture, and also, by getting rid of the starch, we should make our gauze softer and more comfortable to the patient. It seems a remarkable thing that the dye should thus be able to fix the powder. Of course, we understand how the starch does it. The starch particles, becoming attached to the particles of the cyanide, glue them, as it were, to the fibres of the fabric. But how can we explain this dye, in the minute quantity in which we use it, answering the same purpose? I have here some gentian violet dissolved in 50,000 parts of water, and you see the great colouring power that this dye possesses. If I take a piece of gauze and dip it into the solution up to a certain point, you will see the gauze coloured up to that point, but the part that is moistened above by capillary attraction is colourless, showing the avidity with which the fabric seizes the dye. The dye has a remarkable fondness for

[1] See p. 318 of this volume.

the fabric ; at the same time, it is attached to the cyanide, for it is precipitated by it. We can thus understand that the dye may act as a go-between, attaching the cyanide to the fabric by virtue of its affinity for the fabric on the one hand and for the particles of the cyanide on the other. The mode of attachment is altogether different from that by starch, but the thing is done nevertheless. It seems to me astonishing that the dye should have this power. The quantity of gentian violet used is exceedingly small. We take, say, twenty grains of the salt, and diffuse it in sixteen ounces of a liquid containing only 1–50,000th part of the dye, draw a piece of the fabric through it, and so charge it with the requisite amount of the cyanide. If now we consider what proportion the gentian violet bears to the cyanide which it fixes, we find that there is only about one grain of the dye to 140 grains of the salt. But more than that, the molecule, the atom of the dye, is an exceedingly complex and heavy one ; so that if we consider how many there are in comparison with the atoms of the cyanide which it fixes, we find that there is only one molecule of the dye to nearly 600 molecules of the cyanide salt. It is simply wonderful that each molecule of the dye should have the power of fixing such a multitude of other molecules. It seems another instance of what I have ventured to call solid solution. It is not a chemical combination ; it is not a combination of one atom with one atom, but it is an attachment of one molecule with a multitude of other molecules. I have often contemplated with amazement the familiar fact of the solution of a soluble salt in water. Put a bit of common salt into a tumbler of water, and, as everybody knows, it will be quite uniformly distributed in a second or two. This marvellous fact implies that every molecule of the chloride of sodium has an area of a multitude of molecules of water in relation to it. If there were not the arrangement of a definite number of molecules of water round every molecule of chloride of sodium, there would not be an equable solution. So, I conceive, on the same sort of principle, without chemical combination, this dye influences a multitude of particles of cyanide in its vicinity. Here is a piece of gauze charged in the way I have described, and you notice its delicate violet tint ; and we have the satisfaction of knowing that, wherever we see the dye, there is the antiseptic salt. You also observe that, when freely handled, it does not dust materially. Thus we have the two advantages combined, one of which I had not hoped for—that while we have the material dyed so as to show its presence by its tint, it is also prevented from dusting.

Note.—After the above paper had been read, I was mortified to find that some gauze charged by aid of gentian violet dusted to a very inconvenient degree. This appeared to be due to the influence of the bichloride of mercury, which was

used in weak solution (1 part to 4,000) along with the gentian violet in the water in which the cyanide salt was diffused. Bichloride of mercury interferes, to a certain extent, with the precipitation of the gentian violet, and, leaving some of the dye in solution, causes tinting of the gauze independently of the presence of the cyanide salt, and at the same time it impairs the efficacy of the dye in fixing the salt to the fabric. Yet the use of the bichloride of mercury is a matter of great importance, for reasons which I have given elsewhere,[1] and it became necessary to look for some other dye on which the bichloride might not exert this prejudicial influence. I have found that there are several colouring matters which answer the purpose fairly well. Thus both carmine and prussian blue attach the cyanide salt to a cotton fabric perfectly so long as it is moist, but when it is thoroughly dry they are not very good as regards the question of dusting. The dye which I have found to comply best with all the requisite conditions is logwood, or rather the essential ingredient of logwood—haematoxylin, which is a definite crystalline substance, and not unduly expensive.

The manner in which I have found it best to use this substance is the following. It is incomparably better to apply it to the freshly precipitated and wet cyanide than to mix it with the salt after its particles have been aggregated in the process of drying. It may be well to mention here the manner in which the cyanide is prepared. Cyanide of potassium, cyanide of mercury, and sulphate of zinc are mixed together in solution in quantities proportioned to the atomic weights of $2KCy$, $HgCy_2$, and $ZnSO_4 + 7H_2O$; the cyanide of potassium and cyanide of mercury being dissolved together in $1\frac{1}{2}$ oz. of water for every 100 grs. of potassium cyanide, and added to the sulphate of zinc dissolved in three times that amount of water. The precipitate is collected on a strainer, and when well drained is washed with two successive portions of water, equal in quantity to that used for the solutions—viz. 6 oz. for every 100 grs. of potassium cyanide; at least this amount of washing being essential in order to free the precipitate sufficiently from the highly irritating soluble salts which are associated with it in its formation. The precipitate having been thus washed and drained, but not dried, it is thoroughly diffused with pestle and mortar in distilled water (6 oz. for every 100 grs. of potassium cyanide), containing in solution 1 part of haematoxylin for every 100 parts of the cyanide salt, the amount of which is known from the circumstance that the dry product of cyanide salt is almost exactly equal in weight to the potassium cyanide employed. Haematoxylin is readily soluble in a small quantity of hot water and remains in solution when added to a large quantity of cold water. The cyanide salt, while it precipitates the haematoxylin, changes its colour to a pale-bluish tint. This is advanta-

[1] Vide *Lancet*, loc. cit. (p. 309 of this volume).

geously enhanced by the addition of a little ammonia to the mixture, in the proportion of 1 atom of ammonia ($NH_3 = 17$) to each atom of haematoxylin ($C_{16}H_{14}O_6 3H_2O = 356$). More than this proves prejudicial. The ammonia is added in a dilute form, and it is convenient to have the dilution such that one fluid drachm of the ammoniacal liquid shall correspond to one grain of haematoxylin. The dye is further economized by allowing the ammoniated mixture to stand for three or four hours and stirring it occasionally, so that the ingredients may react thoroughly upon each other. If the mixture is filtered immediately, there is considerable loss of colouring matter. The dyed salt having been drained and dried at a moderate heat, is levigated, and may then be kept for any length of time fit for use. When employed for charging a dressing, it is diffused by means of pestle and mortar in solution of bichloride of mercury (1 to 4,000) in sufficient abundance to drench the fabric thoroughly, for which 4 imperial pints to 100 grs. of the salt will be found adequate. This will give a percentage of between 2 and 3 of the cyanide to the dry gauze. For reasons which I have stated elsewhere,[1] the gauze should always be used moist; and if it be prepared for immediate use, as by the dispenser of a hospital, the process of drying may be omitted, the gauze, after being hung up for a while to drain, being deprived further of superfluous moisture by placing it for a while in a folded sheet. It may afterwards be conveniently kept moist by wrapping it in a piece of macintosh cloth. When obtained dry from the manufacturer, it should be moistened again with the weak corrosive sublimate solution before it is used.

[1] Vide *Lancet*, loc. cit. (p. 319 of this volume).

NOTE ON THE DOUBLE CYANIDE OF MERCURY AND ZINC AS AN ANTISEPTIC DRESSING

Contributed by Lord Lister to Sir Hector Cameron's Dr. James Watson Lectures, Glasgow, 1907.

[*British Medical Journal*, 1907, vol. i, p. 795. Together with a later Note.]

I HAVE often regretted that the double cyanide of mercury and zinc is not more generally employed, especially in foreign countries. This is, I feel sure, due to want of acquaintance with it, and I avail myself of the opportunity kindly afforded me by Sir Hector Cameron of saying a few words here regarding its nature, mode of preparation, and use.

Professor Dunstan, of the Imperial Institute, who most kindly undertook to investigate its composition, found it to be a double salt of very unusual type, being a tetrazincic monomercuric decacyanide, $Zn_4Hg(CN)_{10}$. Its insolubility in water appears to be also a very unusual feature in a double salt.[1]

Messrs. T. Morson and Son (of Elm Street, Gray's Inn Road, London, W.C.), to whom I am much indebted for the great pains they have taken in the preparation of the salt, have given me for publication the following formula :—

Pot. cyanid. 98 per cent.	46	parts.
Hydrarg. cyanid.	88	,,
Dissolve in water	240	,,
Zinc. sulphat.	102	,,
Dissolve in water	120	,,

When the solutions are cooled to about 60° Fahr., mix, collect the precipitate, and wash until no precipitate occurs with ammon. sulphid.

The white powder so obtained is dyed with rosalane, ¼ oz. being used to colour 4 lb. of the powder.

I tried various aniline and other dyes, and found none that answered its purpose in all respects so perfectly as purified rosalane (as supplied by Messrs. Meister, Lucius, and Brüning, of Hoechst-on-Main). Its principal object is to attach the cyanide to a fabric charged with it, and this it does with absolute security. At the same time the colour which it imparts to the white powder has the important effect of indicating the presence and distribution of the salt in the fabric.

[1] See *Journal of the Chemical Society* for 1892.

Gauze may be charged by drawing it in several thicknesses through a 5 per cent. solution of carbolic acid in which the dyed cyanide is diffused in sufficient quantity to be about 3 per cent. of the weight of the dry gauze, the liquid being constantly stirred to prevent deposition of the heavy salt.

Old rags or other absorbent fabrics can be readily charged by dipping several layers of them in the 5 per cent. solution of phenol, and dusting one surface with an excess of the powder, which is then diffused by folding the mass, and pressing it till a pretty uniform tint is produced. The absolutely unirritating character of the double cyanide makes a little excess of it in any parts a matter of indifference.

The solution of carbolic acid is used because the cyanide powder is much more readily diffused in it than it is in water, while it destroys any microbes present in the gauze as it comes from the manufacturer. The solution of phenol has the further advantage that it does not receive the slightest colour from the dyed cyanide, so that the depth of tint of the fabric charged with it is in exact proportion to the amount of salt it contains.

The gauze, as supplied by the chemist, is dry, and having lost the carbolic acid used in charging it, may have been subsequently contaminated with septic material. The double cyanide, though very remarkable for its inhibitory power over bacteric development, is without efficacy as a germicide ; and the microbes in the contaminating material would be free to develop in the deep parts of the gauze as soon as the cyanide in them had been exhausted. In case of moderate discharge this would probably never occur, thanks to the slight solubility of the salt and its secure fixation by the dye. But in case of copious effusion of blood and serum, the salt would in time be exhausted, and the microbes in the infective material would be free to develop. In order to guard against this risk, the dressing may either be damped throughout with the carbolic lotion, or, as ample experience has proved to be sufficient, a portion of the gauze in several layers, soaked with the lotion, may be applied over and around the wound and the rest of the dressing used dry.

Bichloride of mercury must not be employed for moistening the gauze, because it forms with the double cyanide a triple compound which is both feebly germicidal and highly irritating.

The double cyanide might, I believe, be very satisfactorily used in military practice as a first dressing, by dusting it over the wound with a pepper box, and covering with any absorbent material that might be at hand. The salt might be used with the utmost freedom, as experience has shown that there is no risk of its producing poisonous effects. Some surgeons who undertook to use the cyanide in this way in the late South African war, had unfortunately no opportunity

of doing so at the front.[1] But Mr. Cheatle informed me that granulating wounds behaved more satisfactorily with the cyanide than with iodoform, while the unpleasant odour of the latter was of course avoided. For further particulars regarding the use of the double cyanide I would refer to an address on the antiseptic treatment of wounds published in the *British Medical Journal* for the 28th of January, and the 11th and 18th of February, 1893.[2] The part in the number for the 18th of February contains the reference to the double cyanide.[3]

[1] Since the above was published I have learned from Mr. Cheatle that he had considerable experience with the use of the double cyanide as a first dressing on the battle-field in South Africa. Having found that the prevailing strong winds made dusting with the powder impracticable, he used a paste made by mixing the salt with a 1 to 20 solution of carbolic acid. This was readily improvised in his tent and was taken to the field in a bottle. With it he smeared the surface of the wound and the surrounding skin, and also his own fingers; thus combining the germicidal action of carbolic acid with the inhibitory effect of the cyanide. Cyanide gauze was then bandaged on. The cases were afterwards under the care of others; but he not unfrequently had the opportunity of seeing them again, and was well pleased with the results obtained. See 'A First Field Dressing', by G. Lenthal Cheatle, *British Medical Journal*, September 8, 1900.

[2] This address is printed at p. 349 of this volume.

[3] See p. 358 of this volume.

AN ADDRESS ON THE PRESENT POSITION OF ANTISEPTIC SURGERY

Delivered before the International Medical Congress, Berlin, 1890.

[*British Medical Journal*, 1890, vol ii, p. 377.]

Mr. President and Gentlemen.—At the International Congress in London, in 1881, Robert Koch demonstrated in King's College his then new method of cultivating microbes upon solid media. The illustrious veteran Pasteur was present at the demonstration ; and at its conclusion exclaimed, ' C'est un grand progrès, Monsieur.' How vast have been the extensions of our knowledge which have resulted from that great step in advance ! Of these none perhaps have been more striking than Koch's own brilliant discovery of the cholera microbe—picked out with unerring precision by his beautiful method from among the multitude of bacteric forms that people the intestinal contents, and grown and studied with as much definiteness as if it were a cabbage or a rose.

But while we have during the last nine years learned so much more of the nature and habits of the micro-organisms which invade our bodies, a new and surprising light has been thrown within the same period upon the means by which the living animal defends itself against their assaults. This we owe to the eminent naturalist Metchnikoff, who, having long carefully studied intracellular digestion in the amoeboid cells which form the main mass of the bodies of sponges and other humble organisms, was prepared to observe and rate at its true value an analogous process in the wandering leucocytes of vertebrata. He found that these migratory cells, with whose amoeboid movement we have been long familiar, feed also like amoebae, and while almost omnivorous in their appetites, have a special fondness for bacteria ; taking them into their protoplasmic substance and digesting them, thus preventing their indefinite propagation among the tissues. The cells which exercise this devouring function he termed phagocytes.

Various objections have been urged against Metchnikoff's views ; but so far as I am able to judge, he has met these effectively by his masterly series of researches ; and his observations have been confirmed and extended by several independent investigators.[1] For the sake of those among my audience who may chance not to be familiar with Metchnikoff's work, I am tempted to relate briefly

[1] See for example Dr. Tchistovitch, *Annales de l'Institut Pasteur*, 25 juillet, 1889, and Dr. Armand Ruffer, *British Medical Journal*, May 24, 1890.

some of his experiments. The green frog, below the temperature of 20° C. (68° Fahr.) is incapable of taking anthrax: the bacilli of that disease cannot grow when introduced under the skin of that animal. To what was this immunity of the frog to anthrax due? Were its juices an unfit pabulum for the microbe, or was the phagocytic action of its leucocytes the explanation? In the hope of solving this question, Metchnikoff formed a tiny bag out of the pith of the reed, and having placed in it some spores of anthrax, closed the bag and inserted it beneath a frog's skin. The pith wall of the bag allowed the animal's lymph to penetrate by diffusion, but excluded the leucocytes: and the result was that the spores sprouted and grew into luxuriant threads of anthrax in the lymph, which was thus proved to be a suitable medium for the growth of the bacillus. Meanwhile under another part of the skin of the same frog had been placed a small piece of the spleen of an animal that had just died of anthrax and contained the microbe in its most virulent form; but there, the leucocytes having free access, no growth occurred.

Another experiment on the same principle was still more instructive. It consisted in introducing the spores of anthrax into the anterior chamber of the eye of a frog, which, as we have seen, is naturally insusceptible of the disease; and also into that of a sheep and of a rabbit rendered insusceptible artificially by 'vaccination' with Pasteur's attenuated virus. The aqueous humour of the healthy eye contains few if any leucocytes to interfere with the perfect transparency essential to vision. Accordingly, the spores sprouted and grew for a while freely in the anterior chamber. Meanwhile, the growth of the bacillus occasioned irritation to the eye, resulting in the immigration of a constantly increasing number of leucocytes, producing turbidity and, in time, hypopion. If a drop of the aqueous humour was withdrawn at an early period after the commencement of the experiment, and examined with the microscope, it was found to contain anthrax bacilli, some of them free in the liquid, but others enclosed in the bodies of leucocytes. But a drop taken after a longer period had elapsed showed no free bacilli, all being now within the leucocytes, and exhibiting signs of degeneration in various degrees as the result of their advancing digestion. Finally the anthrax disappeared entirely and the eye cleared up, the animal in all cases remaining healthy, although inoculation into the aqueous humour proved a peculiarly deadly mode of infecting a susceptible animal.[1]

Here we see that the inflammation excited by the microbe becomes, through the medium of the leucocytes, the cause of its destruction. How little can the lamented Cohnheim have dreamed that his observation of the emigration of

[1] See *Annales de l'Institut Pasteur*, 25 juillet, 1887, pp. 326, 327.

leucocytes in inflammation would prove to have so far-reaching a bearing upon the pathology of infective diseases !

I have brought before you two samples of the kind of evidence upon which the phagocyte theory rests, and if we accept it, as I believe we must, it serves at once to explain much that has hitherto been mysterious in the relations of micro-organisms to wounds. Take, for example, that which the surgeon makes for the cure of hare-lip. Its posterior edge is perpetually bathed with the saliva, which contains many kinds of septic bacteria. But these do not enter and people the fibrine that glues together the cut surfaces, as they infallibly would do if those surfaces were composed of glass or any other chemically inert material destitute of life. It has long been very evident that the living tissues exerted a potent influence in checking bacteric development in such a wound ; but what was the nature of that influence ? This used to be an enigma, but now receives its natural explanation in the phagocytic action of the cells that crowd the lymph soon after its effusion.

At the London Congress I brought forward an experiment which proved that a blood-clot within the body may exert a powerful anti-bacteric agency. I will not repeat the details of that experiment further than to say that a very small piece of linen cloth soaked with putrid blood was mounted by means of silver wire in the interior of a short glass tube open at both ends, which was slipped into the jugular vein of a donkey, and kept in position between two ligatures. After two days the venous compartment was removed, and the coagulum within it investigated. In and near the glass tube it was in a state of advanced putrefaction, as was indicated by its foul odour and greatly altered appearance ; and microscopic examination showed that it abounded with bacteria. But near the wall of the vein it looked to the naked eye like a recent clot ; I could not detect in it any putrid odour, nor could I discover bacteria with the microscope.[1] Stained sections of these outer parts of the coagulum, made after hardening in alcohol, showed great multitudes of cells differing from one another in size and other characters, just as is often the case with Metchnikoff's phagocytes. I supposed that these cells must have been in some way or other the anti-bacteric agents, but how, I could not imagine. The phagocyte theory clears up the mystery.

By means of this same theory we can account for what would otherwise have seemed to me incomprehensible—the use, without evil consequences, of silk ligatures which have not been subjected to any antiseptic preparation. We learn from the experiments of Ziegler and others that leucocytes soon penetrate very thin spaces between plates of glass or other chemically inert foreign bodies inserted among the tissues. And we can understand that they may creep into

[1] See *Transactions of the London International Medical Congress* (p. 275 of this volume).

the intervals between the fibres of a silk thread and destroy any microbes that may have lodged there before they have had time to develop serious septic mischief. But there must surely be a limit to the thickness of the threads. No one, I imagine, would feel justified in leaving in the peritoneal cavity an unsterilized cord as thick as a finger. Dr. Bantock, whose remarkable series of successful ovariotomies may seem to justify his practice, does not, I believe, prepare his ligatures antiseptically; and I understand that he uses, for tying the pedicle of a tumour, silk twist of so strong a nature that it can be trusted to bear the needful strain, with a diameter of only about 1–30th of an inch. But it would surely be wiser to sterilize even so slender a cord. Who can say that septic mischief may not occasionally lurk in the ligature in a form which may baffle the phagocytes?

The success in abdominal surgery achieved by Bantock and Lawson Tait, without, it is said, the use of antiseptic means, proves a stumbling-block to some minds. But in truth the practice of these surgeons is by no means conducted without antiseptic precautions, nor would they, I am persuaded, desire that such an impression should prevail. Both are scrupulously careful in the purification of their sponges, and if there is one thing more important than another in the antiseptic management of wounds of the peritoneum it is the avoidance of impure sponges. Both observe the strictest cleanliness—which is surely an antiseptic precaution—for it owes its virtue to the fact that it presents the septic organisms in the smallest possible numbers and thus reduces their power for evil to the utmost that can be done by any measures that are not germicidal. Both these surgeons also wash out the peritoneum with water so as to get rid of coagula without injuring the peritoneal surface by rubbing it with sponges, and this is done in order to avoid the risk of sepsis in residual clots. The drainage of the peritoneum is another antiseptic measure, and Dr. Bantock, I am informed, has the sponges which absorb the serum wrung out of sulphurous acid, and changes them very frequently.

This is a department of surgery in which I have had but little personal experience. But I can see that while the measures to which I have referred are, so far as they go, highly valuable, it must be in itself a very desirable thing to avoid the direct application to the peritoneum of strong and irritating antiseptic solutions. But now that we are all agreed that microbes are the evil with which we have to contend, it is surely wiser to ensure by germicidal means their entire absence from our hands and instruments rather than trust to the most perfect cleanliness in the ordinary sense of the term. And if water is used for washing out the peritoneum, prudence seems to me to dictate that it ought to be freed entirely from living organisms, if this can be done without making it irritating.

This object is, I believe, aimed at by Dr. Bantock by boiling the water before using it, but I would advise as more effectual an extremely weak solution of corrosive sublimate, such as 1 in 10,000, which, as Koch has taught us, may be implicitly trusted as antiseptic, while it is not appreciably irritating and involves no risk of mercurial poisoning.

In general surgery, the direct application of strong antiseptic solutions is not attended with the same disadvantages as in operations in the peritoneal cavity. My practice for some time past has been to wash the wound, after securing the bleeding-points, with a pretty strong solution of corrosive sublimate (1 to 500) and irrigate with a weaker solution (1 to 4,000) during the stitching, and I have had no reason to complain of the results. To this, however, I must make one marked exception. When applied to the healthy synovial membrane of a joint, the 1 to 500 sublimate lotion produces inconvenient irritation, and therefore, when opening an articulation—as for suturing a transverse fracture of the patella—I abstain from the washing, and, as a substitute, have hitherto irrigated during the whole operation with the weak solution (1 to 4,000).

And yet I must confess that I have for a long time doubted whether either the washing or the irrigation was really necessary. These doubts have been raised partly by experiments—some of which I mentioned at the London Congress—which had proved to me that normal blood and serum, and even pus, were by no means favourable soils for the growth of microbes in the form in which they are present in the air—and partly by reflection upon the experience we had when we used the carbolic spray.

As regards the spray, I feel ashamed that I should have ever recommended it for the purpose of destroying the microbes of the air. If we watch the formation of the spray and observe how its narrow initial cone expands as it advances, with fresh portions of air continually drawn into its vortex, we see that many of the microbes in it, having only just come under its influence, cannot possibly have been deprived of their vitality. Yet there was a time when I assumed that such was the case, and, trusting the spray implicitly as an atmosphere free from living organisms, omitted various precautions which I had before supposed to be essential. Thus, in opening the pleura in empyema for the purpose of evacuating the pus and introducing a drainage-tube and afterwards in changing the dressings, I had previously applied over the opening a piece of cloth steeped in an antiseptic lotion to act as a valve and prevent the entrance of air during inspiration. But under the spray I omitted the valve and allowed the air to pass freely in and out of the pleural cavity, although I used the spray at such a distance from the producing apparatus that it was dry and transparent, with the particles of carbolic solution necessarily widely separated from each other.

And these particles cannot have been in more than instantaneous contact with much of the dust before it was drawn within the chest, and securely protected by the pus or serum there from any further action of the antiseptic. It is physically impossible that the microbes in such dust can have been in any way whatever affected by their momentary presence in the spray.

Yet we did not find our results in the treatment of empyema rendered worse by this false confidence in the spray. There are few more beautiful things in antiseptic surgery, as contrasted with the results of former practice, than to see the abundant purulent contents of the pleural cavity give place at once to a serous effusion, rapidly diminishing from day to day till, the opening being allowed to close, the pleura, restored to its healthy condition, resumes its normal function of absorbing gases ; and, as the natural vacuum within it becomes re-established, the atmospheric pressure blows up the contracted lung, and brings it again into contact with the chest wall unimpaired in its dimensions. Such a case we had witnessed before the days of the spray, and such we continued to see during its use.

If, then, no harm resulted from the admission day after day of abundant atmospheric organisms to mingle unaltered with the serum in the pleural cavity, it seems to follow logically that the floating particles of the air may be disregarded in our surgical work ; and, if so, we may dispense with antiseptic washing and irrigation, provided always that we can trust ourselves and our assistants to avoid the introduction into the wound of septic defilement from other than atmospheric sources.

Since we abandoned the spray, three years ago, we have been careful to compensate for its absence, not only by antiseptic washing and irrigation, but by surrounding the seat of operation with widespread towels wrung out of an antiseptic solution. For the spray, though useless for the object for which it was originally designed, had its value as a diffuse and perpetual irrigator, maintaining purity of the surgeon's hands and their vicinity as an unconscious caretaker. But if besides the spray we give up all washing and irrigation of the wound, our vigilance must be redoubled. Yet I believe that, with assistants duly impressed with the importance of their duties, the task would prove by no means difficult.

I have not yet ventured to make the experiment on any large scale, although I have long had it in contemplation. It is a serious thing to experiment upon the lives of our fellow men, but I believe the time has now arrived when it may be tried. And if it should succeed, then perhaps may be fulfilled my early dream. Judging from the analogy of subcutaneous injuries, I hoped that a wound made under antiseptic precautions might be forthwith closed com-

pletely, with the line of union perhaps sealed hermetically with some antiseptic varnish, and bitter was my disappointment at finding that the carbolic acid used as our antiseptic agent induced by its irritation such a copious effusion of bloody serum as to necessitate an opening for its exit ; hence came the drainage of wounds. But if we can discard the application of an antiseptic to the cut surfaces, using sponges wrung out of a liquid that is aseptic but unirritating, such as the 1 to 10,000 solution of corrosive sublimate, we may fairly hope that the original ideal may be more or less nearly attained.

We have already made of late considerable approaches towards it. Our wounds being no longer subjected to the constant irrigation of the spray, and carbolic acid having given place to the less irritating, though more efficient, solutions of corrosive sublimate, serous discharge is much less than formerly, and less drainage is required. In many small wounds where we used to find drainage imperative we omit it altogether, and in those of larger extent we have greatly reduced it. Thus, after removing the mamma and clearing out the axilla, I now use one short tube of very moderate calibre, where I used to employ four of various dimensions. But it would be a grand thing if we could dispense with drainage altogether ; without applying the very firm elastic compression adopted by some surgeons, which, besides involving the risk of sloughing of parts of low vital power, with the chance that it may after all fail in its object, proves often extremely irksome to the patient.

It remains for me to say a few words regarding the best form of external dressing. Some surgeons have thought that simplicity and efficiency may be combined in the maximum degree by the use of cotton-wool sterilized by heat. But though it may be a simple thing to heat the wool appropriately by means of suitable apparatus in a public institution, for the ordinary practitioner it would be impracticable. And as regards efficiency, I need hardly remark that cotton-wool, merely aseptic, can only exclude septic mischief when it is in the dry state. When it is soaked to its external surface with a copious discharge, it must be liable to become septic *en masse.* And however well we may succeed in the future in diminishing or abolishing discharge from wounds made by the surgeon, there must always remain cases in which it will occur in greater or less amount.

Contused wounds, for example, into which dirty material of one kind or another has been introduced before they are seen by the surgeon, must be purified by the use of powerful antiseptic means, and must, for a while, discharge freely. The same is to be said of cases in which we make the attempt, often with signal success, to restore an aseptic condition in a part affected with septic sinuses. Again, there are abscesses in which, in the present state of our knowledge, we cannot avoid the occurrence of considerable serous oozing, and in which a

perfectly trustworthy antiseptic dressing is a matter of life and death. And whenever discharge is considerable, it is essential that the dressing be of a kind which will not permit the development of septic organisms in it, although it be saturated throughout ; and this can, I believe, only be attained by the use of chemical antiseptic substances.

I have for some time past employed for this purpose a combination of the two cyanides of zinc and mercury, which appears to fulfil the requisite conditions of antiseptic efficacy and due storage of the agent in spite of free discharge, together with absence of irritating properties. Having already published on this subject, I will not detain the members of the Congress with details regarding it, further than to say that since the date of that publication Professor Dunstan, of the London Pharmaceutical Society, has devised means by which the substance can be prepared in a perfectly definite manner, and containing twice as great a percentage of the cyanide of mercury as that which we have hitherto used ; and, as I have ascertained that the cyanide of mercury is the more important ingredient antiseptically, and also that its larger amount in Dunstan's material does not make the salt irritating, we may fairly regard the new preparation as an improvement. And yet we have had no need to complain of this substance in the form in which we have used it hitherto. Those who have followed my practice at King's College Hospital during the year and a half in which this dressing has been employed will agree with me that we have secured a constancy of aseptic results which has more than ever justified the performance of operations once quite unwarrantable.

In thus referring to my own work, I do so, believe me, in no boastful spirit ; but in the hope of stimulating some of those whom I address on this memorable occasion to more thorough earnestness in pursuit of the great objects of antiseptic surgery.

ON THE PRINCIPLES OF ANTISEPTIC SURGERY

[*Virchow-Festschrift.* Bd. iii (1891).]

The fundamental truth on which Antiseptic Treatment in surgery is based is now universally recognised. All are now agreed that the once formidable complications of wounds are caused by living organisms derived from the external world and incapable of originating *de novo* within the animal body. But the practice which has resulted from a recognition of this truth varies greatly in the hands of different surgeons; and it is of great importance to endeavour to ascertain, in accordance with the present state of our knowledge, what are the points which it is essential to attend to, so that on the one hand we may be freed from the encumbrance of needless precautions, and on the other hand may not omit anything which is conducive to such constancy of aseptic results as can alone justify many operations which are in themselves desirable but fraught with grave dangers if septic complications arise.

The original idea of the antiseptic system of treatment was the exclusion of all microbes from wounds. It had long been obvious that the putrefaction which at that period attended all wounds except the very small proportion which united entirely by the first intention, was a grievous cause of mischief. Various antiseptic substances were used to mitigate the evil, but entirely to prevent its occurrence appeared hopeless so long as it was believed, in accordance with the teaching of Gay Lussac, backed by the high authority of Liebig, that the access of a minute quantity of free oxygen could start progressive fermentative changes in organic substances. Where discharge escaped from a wound, oxygen must be able to enter. But when Pasteur had shown that putrefaction and other fermentative changes were caused by the growth of micro-organisms, and had at the same time demolished the idea of spontaneous generation, the problem of the prevention of putrefaction in wounds seemed no longer hopeless. The fermentative microbes could not arise *de novo* in the blood or tissues, and the experience of the absence of all danger in simple fracture seemed to indicate that they could not gain access by any other channel than an open wound. It therefore seemed possible that putrefaction might be entirely prevented in wounds by treating them with some substance which might destroy the life of the microbes, though not excluding the atmospheric gases.

The first attempt to put this idea in practice was made with compound fractures, in which the evils caused by putrefaction were especially manifest

and disastrous ; and the substance which I employed for the purpose was undiluted carbolic acid, a most potent germicide. The experiment answered my most sanguine expectations ; the compound fractures following the same safe and tranquil course as simple ones.

The powerful caustic property of the agent employed was of trivial moment in comparison with the greatness of the danger to be averted in compound fracture, but made it quite unfit for application to incised wounds. But we soon found that carbolic acid could be used with equally good effect under various forms of dilution, so that the application of the principle could be extended to wounds in general. The result was a complete revolution in the practice of surgery. Hospitals which had previously been little short of pest-houses became more healthy than private dwellings had been before ; and operations which had been from time immemorial prohibited on account of their danger were freely and successfully performed.

Meanwhile it soon became apparent that putrefaction was by no means the only evil that was avoided by treatment conducted on these lines. Hospital gangrene, though in itself entirely free from unpleasant smell, disappeared as if by magic, and the same was the case with erysipelas and odourless forms of suppuration. This naturally suggested the idea that various diseases to which wounds were liable, though not septic in the original sense of the word, were, like putrefaction, caused by microbes, each disorder having, probably, its own specific organism ; a view the truth of which has been amply demonstrated by the study of bacteriology, to which the success of antiseptic treatment in surgery gave a powerful impetus.

Thus the attempt to exclude microbes entirely from wounds was followed by results which more than fulfilled the highest hopes entertained of it. Yet the advance of knowledge has shown that to carry out such an idea in its entirety is on the one hand impossible, and on the other hand unnecessary.

It has been ascertained that many common bacteric forms produce spores which resist for a long time the germicidal power of all known agents which could be used in operations. Hence to exclude living microbes entirely from wounds is an impossibility.

It is, on the other hand, happily unnecessary; and that for more reasons than one. In the first place, it appears that none of the bacteria which can cause mischief in wounds are of the spore-bearing kinds,[1] while the sporeless bacteria, such as the various streptococci and staphylococci and the *Bacillus pyocyaneus*,

[1] An exception was once met with by von Volkmann who observed anthrax result from the use of the catgut ligature, prepared, no doubt, from the intestine of a sheep that had died of that disease. But this risk having been pointed out, care is now taken to treat the catgut in such a way as to make such an occurrence impossible.

have been shown by the most careful recent investigations to be deprived of life within a minute by a 1 to 20 watery solution of carbolic acid,[1] the agent which we have always trusted for the purification of sponges and instruments, the hands of the operator, and the integument of the patient at the seat of operation.

These are the points of greatest importance to attend to during the performance of an operation, the once dreaded atmospheric dust being, as it would seem, a matter that may be disregarded. We learn from various independent inquiries that the effects of micro-organisms upon the living body are greatly influenced by the dose, that is to say by the numbers in which they are present at the point of introduction.[2] And this seems to provide a clue to understanding how bacteria in the attenuated and minutely subdivided form in which they are present in the atmosphere may be effectually disposed of by the natural antiseptic action of the blood and the tissues. In pre-antiseptic days this natural antisepsis often triumphed over enormous obstacles, preventing the layer of lymph and coagulum between cut surfaces from putrefying, in spite of the use of unclean sponges, instruments, and hands, and the presence, over the outlet of the wound, of water dressing which, though cleanly when applied, was within a few hours a stinking, putrid mass. But under the converse conditions in which we now operate, this beneficent natural agency may, it seems, be implicly trusted, if the microbes which enter the wound are only such as are deposited from the atmosphere. That such is really the case has become apparent from the uniform attainment of aseptic results by the use of means which could not, as we now see, completely exclude living atmospheric organisms, whether spore-producing or otherwise, during the performance of operations. The carbolic spray, which was introduced for the purpose of destroying the microbes of the air, could not, from its physical constitution, really effect that object,[3] and owed whatever good it did to its properties as an irrigator. But no system of irrigation that can be devised can prevent, during the application of the sutures, the occasional entrance of air into deep parts of the wound from which blood is oozing on which the liquid of irrigation cannot act Yet under the use of the spray or other forms of irrigation the results obtained may be fairly described as uniformly aseptic, when opportunity for efficient antiseptic work was afforded by unbroken skin of sufficient extent for the needful dressings. The complete exclusion of living atmospheric organisms during operations is impossible; but no harm appears to arise from their introduction.

[1] Vide Behring, 'Ueber Desinfection,' &c., *Zeitschrift für Hygiene*, Neunter Band, 1890, p. 417.
[2] Vide W. Watson Cheyne, *Suppuration and Septic Diseases*, Pentland, Edinburgh, 1889, pp. 73 ff.
[3] Vide *Transactions of the Tenth International Medical Congress*, vol. i, p. 32 (p. 336 of this volume).

Confirmation of this opinion has lately come from an unexpected quarter. The glowing accounts published by Koch ten years ago[1] of the antiseptic properties of corrosive sublimate, led us to adopt solutions of that substance in place of the 1 to 40 carbolic lotion for washing and irrigating our wounds. But, beautifully conclusive as Koch's experiments appeared, it turns out that the effects of the bichloride supposed to be due to germicidal action were in reality caused by the inhibitory power which, as was shown by Koch, that agent possesses even when present in extremely minute proportions; and that if, instead of being merely washed away, however carefully, from the objects on which it has been made to act, it is got rid of entirely by converting it into inert sulphide, the original reports have to be toned down to an extraordinary degree. Instead of the resisting spores of anthrax being killed, as we were at first led to believe, by being dissolved in 20,000 parts of bouillon acting for ten minutes, we now learn that a solution of twenty times that strength fails to deprive them of vitality by an action of some hours' duration.[2] And even some sporeless micrococci resist the germicidal action of the bichloride in a most unexpected manner. Thus Behring found that the *Staphylococcus pyogenes aureus* was not destroyed completely by a 1 to 1,000 solution of sublimate in bouillon acting for twenty-five minutes at about the ordinary temperature of wounds, 22° C.[3] Such being the case, we cannot suppose that corrosive sublimate as I have used it can have acted with germicidal effect upon that microbe. My practice has been to abstain from irrigation during the operation, and at its conclusion wash the wound with 1 to 500 solution and irrigate during the application of the sutures with a 1 to 4,000 lotion. As regards the washing, considering its very brief duration and also that the germicidal action of sublimate is greatly interfered with by albuminoid substances, such as the coagula in which the microbes are entangled, I cannot conceive that the process can have acted destructively on any of the *Staphylococcus pyogenes aureus* which might have been deposited on the wound from the atmosphere. And as to the irrigation, it was obviously simply nugatory with respect to that species of microbe.

Nevertheless entire success attended this use of the sublimate; and we are therefore forced to conclude either that the *Staphylococcus pyogenes aureus*, which seems to be the most frequent cause of suppuration in man, never fell upon our wounds during the space of about seven years from the air of our operating theatre, or else that, although present, unharmed by our sublimate lotions, it failed to develop. It has, indeed, been shown by experimental

[1] Vide 'Ueber Desinfection' by Dr. Robert Koch, *Mittheilungen des Kaiserlichen Gesundheitsamtes*, Band I, Berlin, 1881.

[2] Vide Behring, op. cit., pp. 441, 443.

[3] Vide Behring, op. cit., p. 404.

research [1] that the pyogenic organisms are by no means abundant constituents of the dust of hospitals; but their rarity can hardly explain the entire absence of suppuration in our wounds for so long a period, and the fact can, I think, only be explained by the co-operation of the natural antisepsis.

It would, however, be a mistake to suppose that no good can ever be done by corrosive sublimate used in the manner which I have described. Resisting as the staphylococci have shown themselves to that agent, there are other microbes very mischievous to wounds, such as the *Streptococcus pyogenes*, the streptococcus of erysipelas and the sporeless *Bacillus pyocyaneus*, which are destroyed by very much weaker solutions.[2] And it may be well that if, as once occurred in my experience, a careless nurse were to come fresh from fomenting a bad case of erysipelas and, without changing her dress, to hand sponges at an operation, the washing with 1 to 500 sublimate lotion might avert a calamitous attack of that disease.

But if, for the sake of guarding against carelessness on the part of our assistants we think it prudent to wash our wounds before stitching them, it will, I believe, be wise for us, in the present state of our knowledge, to revert to that which we trusted in former years, the 1 to 40 solution of carbolic acid. This agent has been shown to be far more uniform in its action upon micrococci than corrosive sublimate. Behring found that even the staphylococci are killed in a minute by a solution of about the strength mentioned,[3] while, at the same time carbolic acid is not hindered in its action by albuminoid substances in at all the same degree as sublimate is. The 1 to 40 solution, while it appears adequate for the purpose, is far less irritating than the 1 to 20 lotion, and therefore induces less discharge and involves less necessity for drainage. But here, as in other cases, prevention is better than cure; and it must ever be borne in mind that nothing that the surgeon can do can make up for want of care in his assistants. If, for example, a pair of forceps is handed to the operator with the intervals between its teeth occupied by dry septic pus, and a portion of this dirt becomes detached and left in the wound, the evil cannot be corrected by any antiseptic wash that is now at our disposal or any that the world is likely ever to see. Hence I must repeat that our chief attention must be devoted to enforcing scrupulous care on the part of all concerned in the operation in guarding against the grosser forms of septic impurity. Towels dipped in an

[1] Vide Cheyne, op. cit., p. 88.

[2] My colleague Professor Crookshank has ascertained that a cultivation of the streptococcus of erysipelas in bouillon is killed by a solution of sublimate in 4,000 parts of water acting for one minute.

[3] Vide Behring, op. cit., p. 417. Crookshank finds that *Staphylococcus pyogenes aureus* is killed in one minute by 1 to 50 watery solution of carbolic acid.

antiseptic lotion and spread widely round the field of operation are an important aid in this respect.

The foregoing considerations indicate that the troublesome complication of irrigating during stitching may be safely omitted.

The operation being concluded, an external dressing such as shall effectually prevent the access of septic mischief till healing is accomplished is, of course, a matter of essential importance. For this purpose some surgeons have of late years employed materials merely aseptic, such as cotton wadding sterilized by heat. But such a dressing having nothing in it to counteract any accidental defilement, must demand an almost impossible degree of care in its manipulation in order to ensure that it is truly aseptic as left upon the patient. The mere aseptic dressing has also the fatal defect that it is liable to be occasionally soaked to the surface with discharge, in which septic development will then be free to spread inwards to the wound. I believe, therefore, that a dressing, in order to be trustworthy, must be charged with some chemical antiseptic substance. Ideally this substance ought to possess three qualifications; it should be thoroughly reliable in its antiseptic action, it should be capable of being stored up in the material charged with it so that it cannot be washed away by the discharge before the dressing is renewed, and it should be free from irritating properties, so as not to interfere with healing. The nearest approach to this ideal which I have yet met with is presented by a combination of cyanide of mercury with cyanide of zinc. Chemists are not agreed as to whether the two constituents are united in true chemical combination. But however this may be, their association is so intimate that, whereas the cyanide of mercury alone is freely soluble in water and serum and highly irritating to the skin, the combination is almost absolutely insoluble in water and requires about 3,000 parts of serum to dissolve it at the temperature of the human body. Hence, if diffused in a dressing, it remains most efficiently stored in spite of very free discharge; while it is so slightly irritating as not to interfere materially with healing, requiring no protective layer to be interposed between it and the wound. As regards its antiseptic virtues, it is very remarkable for inhibitory efficacy, i.e. for the power of preventing the development of microbes in its vicinity, even in the liquid which tests more severely than any other the antiseptic properties of mercurial compounds, viz. the mixture of serum and blood corpuscles which constitutes the first and most copious discharge from a wound. It is, however, very feeble as a germicide: and in order to make sure that a dressing containing it shall have no hurtful organism alive in it when it is applied, it is well to damp the dressing with a germicidal lotion before applying it. For this purpose a 1 to 20 carbolic solution seems the best that can be em-

ployed.[1] The carbolic acid soon flies off and leaves nothing in contact with the wound but the unirritating cyanide and the fabric charged with it.

In changing the dressing, the skin around the wound is purified on each occasion with carbolic lotion, the wound itself having been previously covered with some trustworthy antiseptic material to avoid the chance of its contamination. These may seem minute details to refer to here ; but in truth they all illustrate principle.

In wounds already septic, attempts are made with more or less success to restore the aseptic state ; but this is a matter on which it is not now needful to enter.

Abscesses, whether acute or chronic, are a field for antiseptic surgery which yields very beautiful results, in striking contrast with those of former practice and at the same time of great pathological interest.

As an example of the former class let us take a case of extensive suppuration of the mammary gland during lactation. Here, under the old system of poulticing, protracted suppuration followed the evacuation of the cavity ; and in spite of free incision, sinuses often remained which could only be cured by laying them open throughout their extent. Under antiseptic management, the abscess being emptied by a puncture sufficient to admit the introduction of a drainage-tube, nothing but bloody serum is found next day upon the dressing, the serous discharge diminishes rapidly, and healing is complete in a very few days, sinus of the mamma being a thing unknown.

To illustrate the chronic class may be taken a psoas abscess consequent on tubercular caries of the spine. Under free incision and poulticing, such cases were almost invariably fatal. If the patient survived the acute fever of the first few days, he perished after a longer or shorter period of hectic caused by protracted free suppuration. But if under antiseptic precautions a drainage-tube is inserted and, without the introduction of any medication into the abscess, a trustworthy dressing is applied, no fever whatever occurs, and the discharge, as in the acute case, is as a rule sero-sanguineous at the outset and afterwards merely serous and soon trifling in amount ; and if scrupulous antiseptic care is maintained a cure is almost always at last effected.[2]

[1] A solution of bichloride of mercury is of little value for this object, inasmuch as it forms with the two cyanides a soluble salt of very feeble germicidal power.

[2] Acting on a hint derived from the Vienna practice of washing out these abscesses with a weak antiseptic lotion and then introducing iodoform and closing the incision, I have of late years washed the cavity with 1 to 10,000 solution of corrosive sublimate and stitched the wound ; dispensing with the iodoform which, I believe, cannot effect what has been expected of it, while it involves a certain risk of iodoform poisoning. The results have been much on a par with those of the Vienna practice. Quite recently, however, we have derived very great advantage from adopting the use of the 'flushing gouge' suggested by Mr. Arthur Barker, by which the pyogenic membrane and all cheesy matter, with sequestra,

When first I witnessed the remarkable fact of the entire cessation of suppuration as a result of relieving abscesses of their contents and at the same time preventing the access of micro-organisms from without, I inferred that microbes could have nothing to do with the production of the pus, but that it was caused by inflammation which, however it had originated, was kept up by the tension of the pent-up liquid operating through the nervous system. This view has, however, been disproved for both acute and chronic abscesses; for the acute by Ogston's observation that they invariably contain micrococci, which experiment has since proved to be truly pyogenic, and for the chronic by Koch's discovery of the tubercle bacillus, which we now know to abound in the pyogenic membrane and caseous material in such cases. Some other explanation is therefore called for. As regards acute abscesses, if we consider what is the primary difference made by a poultice, as compared with an antiseptic dressing, we see that putrefaction is admitted by the former, while it is excluded by the latter. And I conceive that the acrid products of putrefaction act injuriously upon the pyogenic membrane and prevent destruction of the micrococci by the natural antisepsis which is always disposed to operate, but, so long as the abscess is unopened, is hindered by the disturbing influence of tension caused by the rapidly accumulating pus.

In chronic abscesses the slowly increasing contents cause but little tension But we know that a very slight degree of tension on the wall of a cavity containing fluid is sufficient to keep up chronic inflammation in the sac and surrounding tissues. This is well illustrated by the obstinacy of chronic bursitis patellae so long as the bland serous contents remain in the sac; and conversely the rapid cure that takes place when provision is made antiseptically for the escape of the fluid. Not only does the tendency to abnormal effusion of fluid cease, but the inflammatory induration around the sac speedily disappears. And as inflammation, in whatever degree, is always a cause of weakness of the part affected by it, we can understand that, so long as a psoas abscess remains unopened, the enfeeblement of the surrounding tissues, caused in the way referred to, may place the tubercular vertebrae at a disadvantage in their combat with the tubercle bacilli and prevent them from throwing off the disease as they would have done before abscess had occurred, if the spine had been placed at rest in the recumbent posture. If tension is relieved by antiseptic drainage, the tissues are allowed to recover vigour and assert their supremacy. But if such an abscess is poulticed after incision, though tension is removed, far worse causes of disturbance come into operation. The pyogenic organisms, previously absent,

are simultaneously scraped away and washed out. An antiseptic dressing is of course applied to the sutured wound, which may either heal at once throughout or furnish a temporary leakage of serum.

are admitted, and along with them the microbes of putrefaction, the products of which are at first absorbed by the sac and cause the primary toxic fever, but soon by their irritation convert the pyogenic membrane into a huge granulating surface which suppurates like an ulcer under water dressing. The tubercle bacilli meanwhile are allowed to develop at will in the tissues enfeebled by this fresh cause of disturbance.

Even in abscesses with fetid contents antiseptic treatment is often rewarded by brilliant success. I once opened an abscess in the lumbar region, giving exit to a brown liquid, closely resembling thin faeces and with a smell like that of putrid intestines in the dead-house. Being provided with an antiseptic dressing, I applied it, and on changing it next day I was, I confess, surprised as well as delighted to see nothing issue from the opening but a few drops of transparent and odourless serum. Microscopic examination showed the original contents to consist almost entirely of closely packed very slender bacilli in active writhing movement ; of what species I know not. Healing took place rapidly with a typically aseptic course.

In that case I picture to myself the following series of events. The colon was at some spot affected with inflammation not severe enough to cause death of its tissues, but sufficiently intense to prostrate for the time the agency by which, in a healthy state of the bowel, bacteria in the faeces are prevented from passing through its walls. One or more of this particular species of bacillus, having traversed the inflamed intestine, developed in the tissues outside the bowel, and, by a peculiar fermentative action, transformed the effused liquor sanguinis into the offensive material of the abscess contents. This species of bacterium, however, while it throve on this foul pabulum, was unable to grow in pure blood, and when the cavity of the abscess was flushed with liquor sanguinis effused from its wall after it was opened, the microbe ceased at once to develop ; and the abscess followed the same course as if no unusual organism had been present.

Whatever may be thought of this explanation, I venture to urge that all abdominal abscesses with foul contents (excepting those which obviously contain faecal matter) should be afforded the chance of following an aseptic course under antiseptic management.

Submucous abscesses of the rectum pointing beside the anus have always fetid contents, but if carefully treated antiseptically will, as a rule, heal without the occurrence of 'fistula in ano', i.e. without the formation of a communication with the interior of the intestine.[1]

[1] See p. 215 of this volume.

AN ADDRESS ON THE ANTISEPTIC MANAGEMENT OF WOUNDS

Delivered at King's College Hospital in the London Post-Graduate Course, January 18, 1893.

[*British Medical Journal*, 1893, vol. i, pp. 161, 277, 337, with subsequent Corrections.]

THIS day five weeks the patient before you was operated on for a badly united fracture of the patella. He had been kicked on the knee by a horse twelve months previously. In spite of the care of excellent surgeons his limb was in a very useless condition. He could not raise it at all in the extended position, and, in short, he was a complete cripple. When we operated both the upper and lower fragments were firmly adherent to the bone beneath, and separated by a considerable interval. The operation was difficult and protracted, but at length we succeeded in getting the fragments together and fixing them by means of two stout silver sutures. The patient, as you see, can now walk without a stick; he can raise the limb freely in the extended position, and bend it through a limited angle. A useful limb is already assured to him, and he will no doubt acquire in course of time a much greater degree of movement than there is at present. I bring this case before you as an illustration of what may be done by antiseptic measures. In my opinion, such an operation would be unjustifiable unless the surgeon could say to himself with a good conscience that he was practically sure of avoiding septic contamination of the wound. If you consider how terrible the disaster would probably be if septic suppuration occurred after such an operation, I think you will see that I am warranted in this view.

I propose, therefore, now to offer a few remarks as to the principles on which we proceed and the means we employ in order to attain constancy of aseptic results in our wounds. The matter divides itself into two heads: first, during the operation to avoid the introduction into the wound of material capable of inducing septic changes in it; and, secondly, to dress the wound in such a manner as to prevent the subsequent entrance of septic mischief.

As regards the former of these heads, advancing knowledge has enabled us greatly to simplify our procedure. When I first entered upon this subject, knowing as we did that our wounds, with rare exceptions, underwent putrid suppuration, it was natural to suppose that they were very favourable soils for the development of septic organisms. We knew from the experiments of Pasteur that the air of every inhabited place teemed with microbes of various kinds. We

were in almost entire ignorance of the various species of bacteria, and there was no reason then to doubt that any of them getting into a wound would produce serious mischief. Happily, however, we now know the case to be really extremely different. It is but a small proportion of these organisms which are capable of doing mischief in surgery ; and even such species as do produce injurious effects, when they develop in wounds, are by no means always sure of gaining a footing when introduced into them. This depends upon two circumstances. In the first place, we have learned that although putrid blood teems with bacteria of various kinds, some of them in the highest degree pathogenic, normal blood-serum is by no means a very favourable soil for the growth of bacteria, provided that they are in an attenuated condition—not in too strong a dose. I may illustrate what I mean by a simple experiment. If we draw blood, with antiseptic precautions, say from a horse or from an ox, into purified stoppered bottles, and simply place them in a stove at the temperature of the human body, the blood remains permanently unaltered. If we dip the point of the finest needle into already putrefied blood and touch the blood in one of those bottles with the needle so contaminated, and replace the bottle in the stove, to an absolute certainty within twenty-four hours the blood is foul and putrid throughout. But if, instead of applying the putrid blood in substance, I mixed it with an abundance of sterilized water, so as to diffuse the bacteria widely, at the same time washing them of their products, I found that a small drop of this diluted putrid blood, though it contained abundance of bacteria, failed for days together to induce putrefaction. The grossly putrid material—if I may so speak—inevitably causes putrefaction in the blood, but the washed and widely diffused bacteria are unable to do so.[1]

Then there is another even more important point, and that is that the living animal body has the power of defending itself against microbes introduced into it, chiefly, as it appears, by the process of phagocytosis, which Metchnikoff has revealed ; so that if the micro-organisms are not introduced in too large a dose, they are consumed by the wandering cells. These two great truths, then, have been taught us by advancing science : that normal serum is not a good soil for the development of attenuated microbes, and that bacteria introduced among the tissues, if in not too concentrated a form, are disposed of by phagocytosis. The result is that microbes in the form in which they are present in the air are unable to develop in our wounds ; and thus we are able to disregard in our operations the once dreaded atmospheric dust.

Hence we may dispense entirely with irrigation, whether in the form of the spray, which was a kind of irrigation, or in any other ; in fact, our operations

[1] See *Transactions of the International Medical Congress*, 1881, vol. ii, p. 372 (p. 281 of this volume).

may be performed with just the same simplicity as in former years. What we have to attend to is to prevent the entrance into our wounds during operations of the grosser forms of septic mischief, such, for instance, as exist in impure sponges, on dirty instruments, or in any unclean material upon our hands or on the skin of the patient. Then, again, the *entourage* of the seat of the operation must be considered. To speak first of this last point, we cover the region round about the field of operation with towels soaked in a trustworthy antiseptic solution, and then we are quite sure that if we touch any neighbouring object there can be no chance of our contaminating the wound as the result of this contact.

As to the best means of purifying the sponges, &c., it appears that there is, after all, nothing better than the agent which I happened to employ first—carbolic acid. There was a time when, in consequence of Koch's publications on the subject of corrosive sublimate, it to a large extent displaced carbolic acid in the practice of surgeons. It turns out, however, that Koch, able as he is, was misled on a certain point which led him greatly to exaggerate the germicidal power of corrosive sublimate, and that in truth it is for surgical purposes very inferior to a solution of carbolic acid in water. It is a happy thing for us as surgeons that those organisms which have the most resisting spores do not trouble us in surgical work. For instance, the hay bacillus, which is sure to grow in an infusion of hay left exposed for a while, has spores of an exceedingly resisting kind; but supposing the hay bacillus to get into a wound it would do no harm whatever. Again, the anthrax bacillus has very resisting spores, but if we take good care that the catgut which we use for tying bleeding vessels has been treated with an antiseptic that will certainly kill any spores of anthrax with which the sheep might have been affected that furnished the intestines for the catgut, we shall never have any chance of anthrax getting into our wounds. What we have to deal with as our surgical enemies in the shape of microbes are almost exclusively sporeless micrococci. Some of these, however, are much more resisting than others. The *Staphylococcus pyogenes aureus*—a very common cause of suppuration—is very resisting. Now it has been shown that in such solutions as would be used in surgery carbolic acid destroys this organism much more rapidly than bichloride of mercury does.[1]

There is, however, one spore-bearing bacillus with which we have to deal but too often as surgeons, namely the tubercle bacillus. Some experiments were made a few years ago by M. Yersin, at the Institut Pasteur, on the germicidal action of various agents upon tubercle bacilli grown in pure culture on glycerine jelly. I will not enter into the details of his experiments, but if you

[1] See Behring, 'Ueber Desinfection,' &c., *Zeitschrift für Hygiene*, Neunter Band, 1892, p. 417.

refer to his paper [1] you will see that they are very beautiful and very trustworthy. He found that a watery solution of carbolic acid (1 in 20) killed the bacilli in thirty seconds ; carbolic acid (1 in 100) killed them in a minute ; while corrosive sublimate (1 in 1,000), which we had been led to regard as a most potent germicide, required ten minutes for their complete destruction.

But though the bacilli of tubercle, as grown on glycerine jelly by Yersin, seem really to have had spores, yet those spores were in a less resisting form than they assume in the living body. In sputum, for example, they are much more resisting. Accordingly, I lately asked my colleague, Professor Crookshank, to make some experiments for me with reference to the tubercle bacilli as they exist in phthisical sputum, and he has been good enough to do so. I may refer in detail to the method of procedure. On the 13th of December, 1892, three guinea-pigs were inoculated under the skin of the thigh with a little of the sputum which had been subjected for different periods to the action of a solution of carbolic acid in 20 parts of water. Some of the liquid sputum was introduced into a test-tube; to this was added the carbolic solution, in volume about five times that of the sputum. This was shaken up freely and then allowed to stand at rest, and after a certain time the supernatant liquid was poured off from the precipitate. Sterilized water was then poured in in abundance, and shaken up with the precipitate to wash out the carbolic acid ; and of the precipitate which again formed a little was introduced by means of a sterilized pipette under the skin of the animal's thigh. If the bacilli were destroyed, no harm would result to the animal ; if, on the other hand, they remained alive, the fact would declare itself in due time by enlargement of the inguinal glands affected by the tubercle. One portion of the sputum was subjected to the action of the carbolic lotion for one minute ; another portion for an hour ; and a third portion for four hours. Three control experiments were performed ; that is to say, three guinea-pigs were inoculated with sputum which had not been acted on by carbolic acid at all, but treated in a similar manner with sterilized water. I saw those guinea-pigs yesterday. The three which were inoculated with the sputum on which carbolic acid had not acted all had enlargement of the inguinal glands of that side, showing that tubercle had developed there. The one that had received sputum acted upon by the 1 in 20 carbolic solution for one minute had indeed enlargement, but exceedingly trifling compared with that in the other three. The two inoculated with sputum on which the carbolic acid had acted longer, in one case for one hour and in the other for four hours, appeared to have absolutely sound groins ; showing that the tubercle bacilli, in this most resisting form in which we can find them, had been perfectly destroyed by the carbolic-

[1] See *Annales de l'Institut Pasteur*, tome deuxième, 1888, p. 60.

acid solution, 1 in 20, acting upon them for those periods of time; while even one minute had been sufficient very materially to affect them.

Now this is to me a very satisfactory matter, because it gives experimental demonstration of the truth, of which I have long been convinced by experience, that we need not fear tubercle bacilli in our sponges if we keep them for a considerable time in 1 in 20 carbolic lotion. The way in which our sponges are treated is this: they are washed well with soap and water, and afterwards with soda; then thoroughly washed again with water, and finally, after drying, put to steep in 1 in 20 carbolic solution till they are again required for use. For my own part, I purify my sponges for private operations in a somewhat rough and ready way. I put the sponges after an operation into a tank of water, and let them putrefy there. The fibrine, which clings among the pores of the sponges, becomes liquefied by putrefaction. They can then be washed thoroughly clean of their fibrine, and the washing is continued until they no longer give a red colour to water. They are then put into 1 in 20 carbolic solution and kept there. In my Edinburgh practice I used to proceed in a bolder way. Taking the sponges out of the putrid tank, I washed them in water, and sometimes, if I was in a hurry, even before the water which came from them was completely freed from red colour, I dipped them into the 1 in 20 carbolic solution, and took them at once to my operations. I have before now applied a sponge so treated immediately to a wound for the purpose of exercising elastic pressure and absorbing blood and serum from it, and then put on my external antiseptic dressing over it without any bad result. These facts taken together will, I think, be enough to convince you that it is not necessary, as is sometimes done, to discard these most valuable articles and substitute for them sterilized cotton-wool or tissue of one kind or another, incomparably inferior to sponges for the purpose of absorbing blood.

This same 1 in 20 carbolic solution is what we use for purifying our instruments, our hands, and the skin of the patient. For the instruments, it is very much more convenient to be able to purify them by a solution like this than to boil them, as is sometimes the fashion at present. For private practice it would be a most troublesome thing to have to boil your instruments; and even when you had boiled them and brought them sterilized to your operation, it might often happen that an instrument might fall upon the floor or otherwise come in contact with some source of contamination. You could not boil it again before going on with the operation; but the bath of carbolic lotion at once puts it right.

As to the length of time for which the instruments should be kept in the solution, a good deal depends upon the care with which you wash your instruments before putting them away. Any which have teeth, such as forceps,

require special attention. They should always be brushed with a nail-brush before they are dried, so that there may be no crusts of dried blood upon them which the carbolic lotion might require a considerable time to penetrate. If this has been done, a very short period is sufficient for sterilizing. In private practice I put the instruments into 1 in 20 carbolic lotion just before the patient is brought into the room. They continue to be kept in it during the administration of the anaesthetic and during our other preparations, and this is quite adequate for the purpose. It is of great importance that we should not make things unnecessarily complicated.

So also with the purifying of the skin of the patient. It is not needful to apply an antiseptic lotion for hours together, as is sometimes done; a few minutes' action of the 1 in 20 carbolic solution is really sufficient; while its long-continued operation sometimes produces troublesome irritation. For purifying the eyelids before ophthalmic operations the carbolic lotion would excite conjunctivitis. In this special case a weak solution of corrosive sublimate, applied in compresses, is probably the best. It must, however, be continued for a lengthened period.

While carbolic acid is more trustworthy as a germicide for surgical purposes than corrosive sublimate, it is in other respects also greatly to be preferred. Carbolic acid has a powerful affinity for the epidermis, penetrating deeply into its substance; and it mingles with fatty materials in any proportion. Corrosive sublimate solution, on the other hand, cannot be expected to penetrate in the slightest degree into anything greasy; and therefore, as the skin is greasy, those who use corrosive sublimate require elaborate precautions in the way of cleansing the skin—treating it with oil of turpentine or ether, not to mention soap and water, to remove the grease which they feel it essential to get rid of for the efficient action of the corrosive sublimate. Now all this is unnecessary care if you use carbolic lotion. I can testify to this from very ample experience. For my part, I do not even use soap and water. I trust to the carbolic acid, which, by its penetrating power and great affinity for organic substances, purifies the integument as corrosive sublimate cannot.

Our sponges during the operation are washed with 1 in 40 carbolic lotion. You will see how important it must be to have your nurses and assistants careful. In truth, it needs no small pains to teach them to take the care, simple as it is, yet all-important, that is requisite for avoiding the contamination of a wound with gross septic material. Finally, because we cannot be always quite certain of our assistants being as careful as we wish, before we close the wound we wash it with 1 in 40 carbolic lotion. This irritates very much less than the spray, which applied a stronger solution during the whole operation; and in proportion

to the diminished irritation there is less serous effusion, and therefore less necessity for drainage.[1]

Before proceeding to consider the second division of our subject, the best form of external dressing for the wound, I have a few words to say regarding the course you might adopt in case you were called upon to operate under circumstances where you had no chemical antiseptic at your disposal. First, you should have your sponges well boiled, and also the fine silk threads which you will use for securing bleeding-points (the ends being cut short). Such instruments as will not be injured by the process may also be purified in the same way; and for washing the sponges during the operation it will be well to use boiled water, although, from the facts before brought under your notice, you may infer that unboiled water, if free from visible floating particles, would not be likely to cause mischief. Towels dipped in the boiled water and spread about the seat of operation will diminish the chance of contamination of the wound from surrounding objects. Then thorough cleanliness in the ordinary sense, by the free use of soap and water, must be practised for the hands of the surgeon and his assistants and for the skin of the part operated on. For sutures under these imperfect antiseptic arrangements, materials incapable of absorbing putrescible liquids, silver wire, silkworm gut, or horsehair, should be used rather than sterilized silk, in order to avoid suppuration in the stitch tracks.

For dressing the wound in the absence of chemical antiseptics, dry substances such as absorbent cotton-wool or old linen (preferably boiled before use) are far better than anything kept permanently moist, like water dressing. It was shown several years ago by Naegeli of Munich that the more concentrated an organic solution is, the less easily do bacteria develop in it, much in the same sort of way as a cook who makes her jam has to boil it down until the syrup has a sufficient proportion of sugar in it, or else fungi will develop in the preserve. And so the blood and serum oozing into a dry dressing, becoming more or less inspissated by evaporation, are in proportion a less favourable soil for microbic development. If we look back to our old experiences with water dressing, we can only wonder that wounds ever united by first intention at all under such treatment. The water dressing, clean at the moment of application, was invariably stinking when it was taken off in the course of twenty-four hours, and it seems astonishing that septic mischief ever failed to develop in a wound with this putrid mass lying over its outlet. It only serves to illustrate how powerful are the means by which Nature defends herself against the microbes.

But with dry dressing, in conjunction with the care in other respects which

[1] Note by Lord Lister, 1907: In my later practice, when I could feel secure against contamination of the wound by assistants, I omitted the final washing.

I have referred to, you would find that complete primary union, instead of being a rarity as formerly, would be a matter of very frequent occurrence ; although you would not be at all able to reckon upon the constancy of aseptic results which may be obtained by the right use of chemical antiseptics.

Iodoform is an agent very much trusted by some surgeons. It is a very peculiar antiseptic, having extremely little influence over the growth of bacteria outside the body. That was illustrated by a very simple experiment I performed a good many years ago. I took two purified stoppered bottles, and put into one of them cotton-wool strongly impregnated with iodoform—10 per cent. iodoform wool ; and into the other ordinary absorbent wool. I poured milk from a dairy into each, just sufficient to soak the mass of cotton, and left them at the temperature of the air. In one of these bottles the milk was thus most intimately associated with iodoform, yet it soured like that in the other bottle, though somewhat later, and when I examined a little of the iodoform wool under the microscope, I found the milk which it contained teeming with bacteria of different species. That simple experiment was enough to show how little power iodoform exerts over the growth of microbes outside the body. This conclusion has since been amply confirmed by the observations of others. It has been even ascertained, as a matter of experiment, that if iodoform is dusted over sterilized cultivating jelly in a test-tube, growth will take place from organisms that were contained in the iodoform itself.

But though such is the case, it is nevertheless unquestionably true that iodoform exercises a powerful antiseptic influence upon wounds. The most probable explanation of this apparent anomaly is that suggested by Behring, namely, that iodoform produces its beneficial effects, not by acting directly upon the bacteria, but by inducing chemical changes in their toxic products. Behring has ascertained as a matter of fact that some of these toxines are altered chemically by iodoform and at the same time rendered harmless. Two of his experiments, performed in conjunction with De Ruyter, may be quoted in illustration. A ptomaine obtained from a culture of pyogenic micrococci killed a mouse in twelve hours when injected pure into the peritoneal cavity, but proved entirely harmless under similar circumstances when mixed with a little iodoform. Again, a sample of decomposing pus, which had fatal effects when introduced unmixed into the peritoneum of the mouse, had no influence whatever upon the health of the animal if treated with iodoform, which meanwhile left intact the pyogenic microbes.[1] In the absence of their toxic products, the bacteria could do little harm, and would probably soon be disposed of by phagocytosis.

[1] See De Ruyter, 'Zur Iodoformfrage,' *Langenbeck's Archiv*, 1887, p. 984. Some bacteria are more affected than others by the direct action of iodoform. In the special case of the cholera microbe it seems to act as a poison. See Neisser, *Centralblatt für Bacteriologie*, 1888, p. 387.

We seem thus able to understand how iodoform dusted over the cut surfaces of a wound may have great antiseptic efficacy, more especially as it remains for a long time unconsumed among the tissues, and is remarkably free from irritating properties. In circumstances where it is impossible to exclude septic agencies, as in operations upon the mouth or the rectum, or when putrid sinuses are present, iodoform is of very high value. Before applying the iodoform in such cases we mop the cut surface with a solution of chloride of zinc, 40 grs. to the ounce of water, which has a remarkable power of retarding septic changes in wounds in the presence of contaminating materials. On the field of battle iodoform is probably the best means at present at our disposal. Again, in compound fractures, while we endeavour to purify the wound with strong carbolic lotion, we cannot be certain of entire success in this respect, and I should be sorry to dispense with iodoform.

But if you operate when the integument is unbroken, with a sufficient space around you for the application of a dressing, I would not recommend you to use it. To apply it to the interior of the wound would be then entirely superfluous, provided that you have taken care to avoid its contamination while operating, and have at your disposal some trustworthy material for preventing the subsequent access of septic mischief. This, as we have seen, iodoform cannot be expected to do. A porous material impregnated with it, when soaked through and through with blood or serum, will allow the microbes of external defilement to propagate in its substance, though doubtless more slowly than if the iodoform were absent. It is essentially in the interior of the wound that the virtues of iodoform are displayed; and the original Vienna practice of dusting the cut surface with the powder, and applying simple absorbent cotton externally, gave results which were much extolled at the time, and were probably not far inferior to those obtained by the use of iodoform wool or iodoform gauze. An iodoform dressing affords no security against the penetration of septic microbes to the outlet of the wound. At the same time, it is easy to see that circumstances may often arise in which iodoform dusted over the cut surfaces may fail to act effectually; as, for example, when those surfaces are separated by extravasated blood.

Any material that is merely aseptic, such as cotton-wool or gauze sterilized by heat, having nothing in its substance to check in any degree the development of microbes, will allow the septic evil to spread freely to the wound from the external world, if blood or serum happens to penetrate at any point to the exterior. In addition to this fatal objection such a dressing has other disadvantages. The necessary sterilizing apparatus, though it may be provided at a public institution, cannot well be at the disposal of the private practitioner. And, further, the merely aseptic material, having no power to correct any accidental

defilement, must require an almost impossible degree of care in its manipulation. I have seen this system in operation in very able hands with results by no means satisfactory.

An external antiseptic dressing, to be ideally perfect, should have four essential qualities. It should contain some thoroughly trustworthy antiseptic ingredient ; it should have that substance so stored up that it cannot be dissipated to a dangerous degree before the dressing is changed ; it should be entirely unirritating ; and it should be capable of freely absorbing any blood and serum that may ooze from the wound.

The carbolic gauze which we formerly used did, indeed, contain a very efficient antiseptic ; but this, being volatile, was perpetually flying off in spite of our endeavours to fix it, and it was a matter of uncertainty in how many days it might have so far disappeared from the dressing as to leave it untrustworthy. Carbolic acid had also this disadvantage as an element of an external dressing that, acting, as we have seen, with peculiar energy on the epidermis, it interfered seriously with cicatrization, and we were obliged to interpose what we termed a ' protective ' to shield the healing wound from its action. And this gauze, containing resin for the purpose of fixing the carbolic acid, was not a very good absorber of blood and serum. Carbolic gauze, then, was not an ideally perfect dressing.

Corrosive sublimate had the advantage over carbolic acid of not being volatile. But it was readily washed out of gauze or wool charged with it, and under some circumstances it proved very irritating. The discharge, passing from one part of the dressing to another, took up more and more of the bichloride in its passage, and sometimes became so strong a solution of the salt as to cause vesication. I endeavoured to remedy these defects by combining the bichloride with the albumen of the serum of horse's blood.[1] But though the sero-sublimate gauze answered its purpose, in so far that it contained the bichloride better stored up and in a less irritating form, it had inconveniences, especially as regards its preparation, which induced me to abandon it.

The agent which we have found the most satisfactory as the antiseptic ingredient of the dressing is the double cyanide of mercury and zinc.[2] Cyanide of mercury, while it has powerful antiseptic properties, is very soluble and highly irritating ; but the combination of cyanide of zinc with it has the same sort of effect, but in a much higher degree, as the albumen of the sero-sublimate

[1] *British Medical Journal*, October 25, 1884 (p. 301 of this volume).

[2] This is a double salt of a very peculiar constitution. It has been specially investigated by Professor Dunstan, who concludes that it has the following formula : $4ZnCy_2$, $HgCy_2$. See *Trans. Chem. Soc.*, 1892, p. 666. The best way of preparing it was described by Professor Dunstan in the *Pharmaceutical Journal*, third series, vol. xx, No. 653.

gauze had upon the bichloride. The combination with zinc keeps the cyanide of mercury from being dissolved away, and also prevents it from irritating. It is, so to speak, chained down by the cyanide of zinc with which it is combined. The double salt is very little soluble in blood-serum, requiring between two and three thousand parts to dissolve it ; and thus a small quantity of it will last a long time in spite of a free flow of discharge through it. It thus fulfils the condition of persistent storage. It is at the same time practically unirritating ; wounds heal under its immediate contact without the necessity for a protective layer interposed. Then, as to the essential question of its antiseptic virtues. Small as is the quantity which serum dissolves, it proves amply sufficient to prevent bacteric development. Thus in one experiment some serum of horse's blood containing 1–5,000th part of the salt remained clear and odourless for more than a fortnight at the temperature of the body in spite of inoculation with putrid material, and even 1–10,000th part prevented all growth for ten days. When mixed with serum and corpuscles, it prevents putrefaction in smaller quantity than any other antiseptic with which I am acquainted. The greater the amount of albuminoid substances in any solution, the more severely is the antiseptic tested ; and when the red corpuscles are mingled with the serum, as is the case in the first twenty-four hours after the infliction of a wound, a much larger amount of the antiseptic is needed than with serum only. Thus four times as much corrosive sublimate is required to prevent putrefaction in serum and corpuscles as in serum. Now, the double cyanide answers the purpose in half the quantity that is necessary with corrosive sublimate. As an illustration of the practical value of this material, I may mention a single experiment, not hitherto published. I packed a piece of glass tube with gauze charged with 3 per cent. of the double salt, and poured into it serum and corpuscles obtained by whipping pig's blood. I then inoculated one end of the saturated gauze with a drop of septic serum, and kept it at the temperature of the body, with provision for preventing evaporation. After the lapse of five days I found the entire mass of gauze pure in odour and without bacteric development, as tested by microscopic examination of stained cover-glass preparations of the contained blood. Meanwhile a piece of unprepared gauze similarly treated showed bacteric development within twenty-four hours.

But here I must remind you of the essential difference, which must always be kept in view in considering antiseptic agents, between germicidal and inhibitory power ; that is to say, between the capability of destroying the life of microbes and that of preventing their growth while the agent remains in contact with them. These two properties are by no means similarly proportioned to each other in all antiseptics. Thus, cyanide of mercury is far superior to the

bichloride in inhibitory power, but very inferior to it as a germicide. And the double cyanide of mercury and zinc, while admirable as an inhibitor, is very feeble as a germicide ; so that we can have no security that materials charged with it may not contain living organisms. Hence if gauze charged with the double cyanide were applied dry to a wound, the time might come when, if the discharge were free, the salt, in spite of its slight solubility, might be all washed out of the deepest parts of the dressing ; and as soon as this should be the case, living microbes contained in it would be free to develop towards the wound. In order to guard against this risk, we treat the gauze before using it with a reliable germicide. That which we now use for the purpose is the 1 to 20 solution of carbolic acid, which, besides being thoroughly effective, has the further advantage that it soon flies off from the dressing and leaves nothing in contact with the wound but the unirritating double cyanide and cotton fabric.

And now I wish to correct a mistake I made in a former publication.[1] For the purpose of destroying any microbes that there might be in the gauze, I recommended a solution of corrosive sublimate, 1 to 4,000. Now we have seen that the 1 to 4,000 sublimate lotion is not nearly so powerful as a germicide as we then supposed. But it further appears that such power as it possesses is almost entirely lost as soon as the bichloride comes in contact with the cyanide of mercury and zinc, when a curious soluble triple compound[2] is formed which has extremely slight germicidal action.[3] The triple salt seems also to be highly irritating ; and thus, when we used the bichloride of mercury, we failed almost entirely to obtain the object for which we employed it, and at the same time lost some of the goodness of the double cyanide, part of which was washed out in the process, while the resulting solution might cause troublesome irritation. Soon after I first described this dressing, a surgeon at one of our hospitals came to me and said he had been using it, and found great inconvenience from it. He had applied it to a scalp wound, and the whole of the skin covered by the dressing was excoriated. I found he had applied it soaking wet with bichloride lotion, and we are now able to understand the irritation that resulted.

It is quite unnecessary to have the gauze wet with the 1 to 20 carbolic lotion ; mere dampness is sufficient. It may be conveniently moistened as follows : The gauze is commonly sold in pieces of three or six yards, folded lengthwise in eight layers. These are unrolled, and half the number to be moistened are sprinkled roughly with the lotion. The wet and dry pieces are then superposed alternately, and the whole rolled firmly together ; and in a few minutes the

[1] See p. 319 of this volume.
[2] See Varet, *Comptes Rendus*, 1888, vol. cvi, p. 1080.
[3] For the determination of this fact I am indebted to my colleague, Professor Crookshank.

entire mass will be uniformly damp. This may be done by a nurse, who then folds the gauze up in a piece of macintosh cloth in which it is kept till it is required for use, the precaution being taken of turning over the edge of the jaconet so as to prevent the cotton from coming in contact with the gauze, and abstracting the carbolic lotion by capillary attraction. Used in this way the double-cyanide gauze may be absolutely trusted for excluding mischievous microbes ; and we have seen that it contains the antiseptic element excellently stored up, and that it does not irritate ; and when I add that it is all that can be desired in absorbing power, you will see that it approaches very closely to our ideal. And having now employed it constantly for over four years, both in hospital and in private practice, with thoroughly satisfactory results, I feel entire confidence in recommending it to you.

Here is a sample of the gauze ready for use. It is, you observe, of mauve colour, whereas the pure cyanide of mercury and zinc is a white impalpable powder. I have fully explained elsewhere the reasons for using a dye,[1] but I may here shortly recapitulate them. When the pure salt is diffused in water, and a piece of gauze is charged by drawing it through the liquid and dried, it is found that the powder dusts out of the gauze on the slightest touch, and irritates the nostrils extremely. I first remedied this defect by means of starch ; and having observed that starch in solution in water becomes attached to the particles of the double salt and completely precipitated with it, it occurred to me that perhaps some colouring matter might behave in the same manner as the starch, and that thus it might be possible to dye the colourless salt, and so have the means of judging, by the tint of the gauze charged with it, whether or not it was uniformly distributed in the fabric. I found on trial that various dyes did indeed behave as I hoped, including colouring matters so different as Prussian blue, logwood, and various aniline dyes. But, what I had not at all anticipated, it turned out that in the case of some of these dyes, when the coloured precipitate was diffused in water and the gauze was drawn through the mixture and dried, without the use of any starch, the objectionable dusting was avoided. The particles of dye, though in extremely small proportion to those of the salt, attached them, as it would appear, to the fabric.

When I last published on the subject,[2] I recommended haematoxylin for this purpose. But I have since ascertained that the effect is produced still more satisfactorily by an aniline dye, the hydrochlorate of mauveine, known in commerce by the name of purified rosalane.[3] I have here a sample of the

[1] See p. 325 of this volume.

[2] Vide loc. cit.

[3] This dye may be obtained from Messrs. Meister, Lucius, and Brüning, of Hoechst-on-Main. I may here publicly express my thanks to Dr. Perkin, to whom the world is indebted for the aniline dyes, for

mauve-coloured powder, the dyed cyanide, as supplied by Messrs. Morson, of Southampton Row. For charging gauze it is diffused with pestle and mortar in 1 to 20 solution of carbolic acid in the proportion of about 30 grs. to a pint; and the gauze, which must be of thoroughly absorbent quality, is drawn, in a thickness of about eight layers, through the liquid, which is conveniently placed in a trough having a bar near its lower part, beneath which the gauze is made to pass, care being taken that the liquid is kept perpetually stirred to prevent precipitation of the salt. The gauze is then hung up to dry at the temperature of the air. The carbolic lotion is used in preference to water, both because the powder is very much more easily diffused in it and because it is desirable that any dirty material which the gauze may happen to contain may be sterilized. A very cheap kind of carbolic acid will answer, and the solution that drains from the gauze when it is hung up may be used again for the same purpose. It thus scarcely adds to the expense of the preparation.

This is a very simple process. For a whole year I prepared my own gauze, for use in hospital as well as in private practice, before I had satisfied myself completely as to its value. For hospital use I would advise that the gauze should be prepared in the institution, so as to save the manufacturer's charges. In that case it may be taken down and wrapped in macintosh when only partly dry, avoiding the trouble to the nurses in moistening it.

Gauze may also be easily charged at a few minutes' notice for emergency in private practice. I have here a 6-yd. piece of unprepared absorbent gauze folded lengthwise in eight layers. I soak this thoroughly with 1 to 20 carbolic lotion, and dust some of the powder roughly over one surface with a pepper-box. I then roll it together, and kneading it for a minute or two with the fingers, produce, as you see, a sufficiently uniform diffusion of the salt throughout the mass, as indicated by the colour.[1] If this were done by a nurse before the commencement of an operation, and the wet gauze were wrapped in a folded sheet to absorb redundant moisture, it would be ready for use when required. A 6-yd. piece would be an ample dressing for many cases. Now I see by the amount that has gone from the pepper-box that not more than one-fifth of an ounce has been used, and as Messrs. Morson supply the dyed cyanide at 20*s.* per lb., this implies a cost of only 3*d.*, so that it cannot be regarded as expensive.[2] If you have no

his kindness in ascertaining for me the chemical composition of rosalane. It is used in quantity equal to ½ per cent. of the weight of the double cyanide, and is applied in watery solution, in which the salt, after being freed from excess of cyanide of mercury by repeated washing, but before it has been dried, is thoroughly diffused by stirring. The salt as it precipitates carries the dye down with it, and is afterwards dried at a moderate temperature.

[1] A pair of leather gloves may be worn to avoid staining of the hands, or the dye may be washed from the fingers with spirit of wine.

[2] I found on weighing this piece of gauze when it was dry that it was needlessly heavily charged,

absorbent gauze at your disposal, linen rags, which are excellent in absorbing quality, may be quite well charged in a similar manner. This old towel which has been so prepared, if folded a few times, would make a perfectly satisfactory dressing. Bandages which it is desirable to render efficiently antiseptic, such as one that is to be applied next the skin for keeping down the soft parts in a stump after amputation of the thigh, may be charged on the same principle.

When a free discharge is anticipated we apply a piece of thin macintosh, sponged with carbolic lotion, over the exterior of the dressing, to prevent the blood and serum from passing directly through it. This arrangement no doubt interferes somewhat with the inspissation of the discharges by evaporation, but this is a matter of indifference when the dressings are efficiently antiseptic.

There is another use to which the dyed cyanide powder may be often advantageously put, namely, treating it with enough of the 1 to 20 carbolic lotion to make a sort of soft mud or cream which may be applied with a camel's-hair brush to parts where there is very little space between the wound and some source of septic contamination. I have by this means been repeatedly able to avoid suppuration in the vicinity of the anus, as I otherwise might have failed to do. The store of the antiseptic salt upon the skin prevents the microbes from working their way into the wound under the narrow strip of dressing alone available. There are also situations, such as the pubes, where the cyanide cream applied to the hairs converts them with great advantage into a part of the antiseptic dressing.

I may be asked how it was that I obtained uniformly good results when I used corrosive sublimate solution for the purpose of producing a germicidal effect upon the gauze ; for I do not exaggerate when I say that during nearly two years in which I followed this practice I did not meet with a septic failure when I had an unbroken skin to deal with and a fair field around for the dressing. This success was no doubt partly due to the slight solubility of the double salt preventing it from being washed out of the deeper parts of the gauze. But I attribute it also to another circumstance. I invariably washed a substantial mass of the gauze which was to be applied next the wound in 1 to 20 carbolic lotion, in order to get rid of the irritating bichloride which it contained. I thus—though unintentionally—effectually sterilized, not only this portion of the gauze, but also neighbouring parts into which the redundant carbolic liquid soaked. And this mode of procedure, though not so perfect as the systematic moistening of the entire mass, is a rough-and-ready way of attaining much the same result.

In changing the dressings we make it an invariable rule to cover the wound

containing 7 per cent. of the salt instead of 3 per cent., which is that ordinarily used. Thus the salt required for such a dressing does not really cost $1\frac{1}{2}d$.

with something reliably antiseptic before we wash surrounding impure parts, so as to avoid the chance of defiling the wound with them. For these washings we use the 1 to 40 carbolic lotion. As to the times for changing the dressings, it is no doubt true that that which is applied immediately after the operation might in most cases be left untouched for several days. Nevertheless, when discharge is free, I prefer, as a rule, to remove the first dressing when the first twenty-four hours have passed. We thus get rid of the serum and corpuscles, which, while they constitute the largest amount of discharge which occurs in the case, test, as we have seen, our antiseptic dressings the most severely. The discharge being still moist near the wound at this period, the gauze is lifted from it without disturbing it in the slightest degree ; and I never knew a patient fail to express himself as feeling more comfortable when the first dressing had been changed. There are, however, special cases, like a stump after amputation of the thigh, where an exception may be made on account of the disturbance of the wound that the changing of the dressing would involve.

In conclusion, I may remark that it pleases me, as the years pass, to see the hope which I expressed at the International Congress in London eleven years ago in course of fulfilment, namely, that the use of the antiseptic system would gradually spread by leavening action throughout the world. At the same time, I am sorry sometimes to observe that unnecessary trouble is often taken in some directions while essential points are disregarded in others ; so that, with the best intentions, the best results are not always obtained. I venture to hope that this address may be of some use to you in directing your attention to the essential conditions of success.

ON SOME POINTS IN THE HISTORY OF ANTISEPTIC SURGERY

[*Lancet*, 1908, vol. i, p. 1815; and *British Medical Journal*, 1908, vol. i, p. 1557.]

[The following unfinished letter to Sir Hector Cameron was written early in 1906, before the delivery of his *Lectures on the Evolution of Wound Treatment*, but never sent to him. I have been assured that it would have sufficient interest for some readers to warrant its publication.]

My dear Cameron.—It seems superfluous for me to write anything to you with reference to your coming lectures.[1] But perhaps in what I shall say, there may be here and there points which may interest you.

In treating surgical cases antiseptically, I always endeavoured to avoid the direct action of the antiseptic substance upon the tissues, so far as was consistent in the existing state of knowledge with attaining the essential object of preventing the development of injurious microbes in the part concerned.

In compound fracture, to which in 1865, I first put in practice the antiseptic principle, I applied undiluted carbolic acid freely to the injured part, in order to destroy the septic microbes already present in it; regarding the caustic action which I knew must occur as a matter of small moment compared with the tremendous evil which it was sought to avoid. But when this had once been done, no further direct action of the antiseptic upon the tissues occurred. The carbolic acid formed with the blood a dense chemical compound which, together with some layers of lint steeped in the acid, produced a crust that adhered firmly to the wound and the adjacent part of the skin. This crust was left in place till all danger was over, its surface being painted from time to time with the acid, to guard against the penetration of septic change into its substance. Meanwhile, in the undisturbed wound the beautiful result occurred that the material of the crust within it, and the portions of tissue which had been destroyed by the caustic, were replaced by living tissue formed at their expense.

That dead tissue, when protected from external influences, was so disposed of, was a most important truth new to pathology; and it afterwards suggested the idea of the catgut ligature.

[1] 'The Dr. James Watson Lectures delivered at the Faculty of Physicians and Surgeons of Glasgow in February, 1906.' Glasgow 1907.

I do not remember whether you saw the case that led me to apply the antiseptic principle to abscess. The patient was a woman above the middle period of life, with lumbar abscess. Taught by the disastrous results that sooner or later followed the evacuation of such abscesses, whether by valvular opening or by cannula and trocar, I left the case undisturbed ; till one day, on looking at it, I found that nothing but epidermis seemed to intervene between the pus and the external world, so that if left for another day it would in all probability burst.

I therefore resolved to open it and apply a dressing which should imitate, as much as circumstances permitted, that which we used in compound fractures. The pus which escaped on incision was as thick as any I ever saw. Mixing some of it with undiluted carbolic acid, I applied some layers of lint soaked with the mixture to the wound and surrounding skin, and covered them with a piece of thin block-tin moulded to proper shape, such as we used for covering the crust in compound fracture. This metal covering, which prevented loss of carbolic acid by evaporation and soaking into surrounding dressings, was fixed by strapping, and a folded towel was bandaged over it to absorb discharge.

Next day, on changing the dressing, I was greatly astonished to see nothing escape from the incision except a drop or two of clear serum. What was now to be done ? I had no longer any pus to mix with the carbolic acid. But it occurred to me that I might make a satisfactory crust by mixing carbolic acid with glazier's putty. Accordingly I sent to the dispensary for some whiting and boiled linseed oil, and making a solution of one part of carbolic acid in four of the oil, rubbed it up with whiting in a mortar, thus making a carbolic putty. This I spread on a piece of block-tin and applied it as I had done the first dressing. There never was any further discharge of pus ; the serous oozing diminished rapidly, and before long healing was complete.

In that case, as there was no spinal curvature, I could not be sure that the abscess was connected with the vertebrae. But similar results afterwards followed the same treatment where discharge of bone showed that such connexion existed, and also in suppuration of the hip-joint, whether attended with shortening of the limb or not, scrupulous care being taken to keep the affected part completely at rest. The time required for final closing of the sinus was, however, generally much longer than in the first case.

Precisely the same beautiful result, so entirely novel and so full of deep interest both for pathology and practice, was seen when acute abscesses were treated in the same way ; the only difference being that in the acute cases the serous oozing which followed evacuation of the pus came much more rapidly to a conclusion.

In order to ensure freedom of escape for the serum, a narrow strip of lint soaked with a solution of carbolic acid in four parts of olive oil was inserted in the incision. But the antiseptic substance was never from first to last applied to the cavity of the abscess, as such treatment could only have been productive of needless irritation.

I continued to use a strip of lint as a drain for about five years with perfectly satisfactory results. But in 1871, having opened a very deeply seated acute abscess in the axilla, I found to my surprise, on changing the dressing next day, that the withdrawal of the lint was followed by escape of thick pus like the original contents.

It occurred to me that in that deep and narrow incision, the lint, instead of serving as a drain, might have acted like a plug, and so reproduced the conditions present before evacuation. Taking a piece of the india-rubber tubing of a Richardson's spray producer that I had used for local anaesthesia at the operation, I cut holes in it and attached knotted silk threads to one end, so improvising a drainage-tube. This I put to steep for the night in a strong watery solution of carbolic acid, and introduced it in place of the lint on changing the dressing next morning. The withdrawal of the lint had been followed by discharge of thick pus as before; but next morning I was rejoiced to find nothing escape unless it were a drop or so of clear serum. This rapidly diminished, and within a week of the opening of the abscess I was able to take leave of my patient, the discharge from the abscess cavity having entirely ceased.

After that case I used drainage-tubes as a rule in the treatment of abscess. But it is well to remember that if such a tube should not be at hand, a narrow strip of lint, sterilized of course with some trustworthy antiseptic solution, will in almost every case answer the purpose equally well.

The crude carbolic acid which, under the name of German creosote, was supplied to me by my colleague, Dr. Anderson, Professor of Chemistry in the University of Glasgow, was a brown liquid which had been adulterated with water, and this lay on the top as a clear layer, destitute of any flavour of carbolic acid. This led me in my first paper on compound fracture to speak of carbolic acid as absolutely insoluble in water.[1] But when it was afterwards produced in a comparatively pure condition in colourless crystals, it proved to be capable of being taken up by water, though twenty parts were required for the purpose. The watery solution, however, though weak numerically, showed itself to be exceedingly potent as an antiseptic. Having applied it to a foul sore in the palm of the hand, I found, on changing the dressing next day, that all putrefactive odour had disappeared.

[1] See p. 4 of this volume.

This enabled me to use carbolic acid for washing wounds after operations, and so to extend the application of the antiseptic principle to surgery in general. In the state of knowledge at that early period it seemed imperative to apply a powerful germicide to the wound before closing it. To use undiluted carbolic acid for operation-wounds, as I had done in compound fracture, was out of the question ; and carbolic oil, though I did indeed try it, was ill adapted for the purpose. But the watery solution could be satisfactorily used not only for washing the wound, but also for purifying the surrounding skin, the hands of the operator, and the instruments.

The entire absence of carbolic acid in the layer of water on the 'German creosote' with which I made my first attempts with compound fractures indicates that there were present in the crude product substances for which the acid had incomparably greater attraction than it had for water. When purified from these substances, it is indeed soluble in water, but only in small amount; and being so feebly held by water, it is free, when in watery solution, to act upon other matters for which it has stronger attraction. Thus was explained the remarkable germicidal energy of a lotion containing only a twentieth part of carbolic acid, as illustrated by the foul sore in the hand before referred to.

With linseed oil, on the other hand, the acid could be mixed in any proportion, and being firmly held by the oil, it was mild in action, though present in the large proportion of 1 to 4, as used in the carbolic putty. The 1 to 4 carbolic oil is bland when applied to the tip of the tongue, whereas the 1 to 20 watery solution is intolerably pungent.

The acid in the watery solution, while potent in action when applied, is soon dissipated, whereas it is slow in leaving the oil. Hence the watery solution, powerful but transient in operation, was admirably adapted for application to a cut surface as a detergent, while the carbolic putty, bland in action and serving long as a store of the antiseptic, could be used with good effect not only for abscesses, but also as an external dressing for operation-wounds ; and for that purpose I long employed it. The putty was used in a layer spread on calico, freely overlapping the skin around the wound, and covered with a folded cloth to absorb the serum that flowed from beneath its edges. Although this mode of dressing gave place in time to others which were more convenient, the change effected under its use at that early period was of the most striking character : healing without suppuration, pain, or fever, instead of being the rare exception, became the rule, and operations were safely performed which had previously been utterly prohibited on account of the danger that attended them ; while pyaemia and hospital gangrene, which had before been disastrously rife, were banished from my wards.

Epidermis is a substance for which carbolic acid has special attraction; and this, coupled with the facility with which the acid blends with oily matters, renders it peculiarly fitted for purifying the skin about the seat of operation and the surgeon's hands. Another property which aids its action as a detergent is its great penetrating power, not limited by the products of its chemical action upon organic substances.

I used the 1 to 20 watery solution for rendering the patient's skin and the hands of myself and my assistants aseptic throughout the 40 years during which I practised on the antiseptic principle, and I never had any reason to doubt its efficacy. No long time is required for its action. In my private practice the purification of the skin was, as a rule, not begun till I entered the patient's room to perform the operation. The part concerned was then thoroughly washed with the 1 to 20 carbolic solution, and was kept covered with lint soaked with the same lotion while the instruments were being attended to and the anaesthetic administered; the whole process occupying only about a quarter of an hour. Yet experience showed that this brief period was sufficient.

It may perhaps be argued that under the carbolic putty or any other dressing containing carbolic acid, that volatile agent was perpetually acting on the skin, and may have made up for deficiences in the original purification. But during several years before I gave up practice, the dressings did not owe their virtues to any volatile antiseptic.

I may mention in illustration one of my latest operations. The patient was a lady advanced in years, with a large ventral hernia below the umbilicus. It was producing serious symptoms; and attempts to reduce it having failed, her condition had become exceedingly grave. I only began to disinfect the skin when she was already partly under the influence of the anaesthetic. The umbilicus contained some drops of opaque liquid of a highly offensive character. I cleansed its folds carefully with the 1 to 20 carbolic solution, and washed the skin over and around the sac with the same lotion. The sac was opened by a median incision, the upper end of which extended to the umbilicus. Into further details of the operation I need not enter. On changing the dressing (of cyanide gauze) it appeared that, in her frail condition, the margins of the skin at the upper end of the incision had lost their vitality over an extent of about half an inch in length and one-tenth of an inch in breadth at each side. I afterwards left the dressing unchanged for several days, when I found that the sloughs, the upper ends of which encroached on the umbilicus, so foul before the operation, had been replaced by new living tissue, and complete cicatrization had occurred without the formation of a particle of pus.

I cannot but think it a happy circumstance that the substance which

I employed first in endeavouring to apply the antiseptic principle should have been so admirably adapted for detergent purposes. And it has grieved me to learn that many surgeons have been led to substitute needlessly protracted and complicated measures for means so simple and efficient.[1]

As an instance of trouble misapplied in this matter, may be mentioned preliminary washing with soap and water. If carbolic acid is the disinfectant used, such washing is not only wholly unnecessary, but is, I believe, positively injurious; as it must tend to check the penetration of the germicide into the substance of the epidermis, by saturating it with water for which carbolic acid has so little affinity. That this practice is superfluous is, I venture to think, proved by my experience, as I never in any case adopted it.

The incomparably greater attraction of carbolic acid for epidermis than for water was strikingly illustrated by an experiment not hitherto published.

[Here my letter was broken off, in consequence of other engagements. But I afterwards wrote to Sir Hector Cameron what I had intended to say on this subject and he was good enough to incorporate my remarks in his second lecture (see *British Medical Journal*, April 6, 1907, p. 799).]

'The avidity with which carbolic acid seizes upon epidermic tissues was strikingly illustrated by an experiment which he related in an unpublished address to the medical students of Glasgow, delivered in 1894.

'Having discovered a method by which the amount of carbolic acid present in a watery solution could be determined,[2] he packed a test-tube closely with hair of the human head, and added just enough five per cent. solution of carbolic acid to cover it, eight times the weight of the hair being required for the purpose. Half an hour later he poured out some of the liquid, and applied the test; when it was found that already nearly half the carbolic acid had been withdrawn by the hair from the watery solution.

'Considering that the hair was only an eighth part of the weight of the solu-

[1] The fear sometimes expressed of poisonous effects from carbolic acid, as used in antiseptic surgery, is, so far as my experience goes, entirely groundless.

[2] 'In the course of some work on the preparation of catgut for surgical purposes, he observed that if a weak solution of chromic acid in water is mixed with carbolic lotion, the mixture, which is at first a pale straw colour, gradually grows very much darker during the next few hours. This fact afforded the means of estimating the quantity of carbolic acid in a watery solution. Making a mixture of equal parts of the weak chromic liquid and a five per cent. watery solution of carbolic acid to serve as a standard of comparison, and at the same time making a corresponding mixture of the chromic liquid with the carbolic solution to be tested, and ascertaining how much the standard had to be diluted in order to bring its tint down to equality with that of the mixture containing the liquid to be tested, an estimate could be formed of the amount of carbolic acid present in the latter. Lord Lister informs me that, on going over the subject again recently, he ascertained that hair retains this remarkable power of withdrawing carbolic acid from a watery solution after all fatty matter has been removed from it by prolonged steeping in sulphuric ether.'

tion, this was certainly very remarkable. The hair must thus have become charged with about a sixth of its weight of the antiseptic [1]; and if a larger quantity of the lotion had been used, the proportion would have been still greater.' [2]

[1] 'Hair thus highly charged with carbolic acid by washing with five per cent. solution, may sometimes be turned to account in surgery of the scalp as an effective and unirritating antiseptic dressing. This may be illustrated by one of Lord Lister's latest cases. The patient was a lady with numerous atheromatous tumours scattered over the scalp. To have shaved around each of these would have caused a very inconvenient loss of hair ; but this was avoided by washing freely with the lotion about each tumour, and simply passing a comb along the line where the incision was to run, the hair being replaced in position after the removal of the cyst. The several tumours having been so dealt with, a cap of folded cyanide gauze was bandaged over the head, and when this was removed some days later, all the wounds were found to be healed.'

[2] *On the Evolution of Wound-treatment during the last Forty Years*, p. 71, and *British Medical Journal*, April 6, 1907, p. 799.

PART IV

SURGERY

REPORT OF SOME CASES OF ARTICULAR DISEASE OCCURRING IN MR. SYME'S PRACTICE, EXEMPLIFYING THE ADVANTAGES OF THE ACTUAL CAUTERY

[*Monthly Journal of Medical Science*, August 1854.]

CASE I.—*Omalgia, Application of the Actual Cautery; Cure.*

MARGARET ASHTON, aet. 25, admitted the 25th of October, 1853; a servant; has generally enjoyed good health, and has a very robust appearance. Four months ago, after exposure to wet and cold in washing, she had a severe fit of shivering, and was seized a few days after with pain in the right shoulder, just below the acromion, so severe that she could scarcely lift the arm; this lasted about twelve hours, and was followed in the course of the next day by intense pain in the left shoulder, below the back part of the acromion. From that day till her admission, she was unable to raise the arm; the pain was for the first two months extreme, keeping her as if 'in the fire all night', and banishing sleep almost entirely. During the last two months she has rested from work, and has suffered less. On admission she complained of constant gnawing pain in the left shoulder, and extending down the limb as far as the elbow, and sometimes to the fingers; when in the sitting posture she held the affected limb with the other hand, to ease the pain; the arm was also affected with a feeling of numbness and weakness; and although the shoulder was not very tender on pressure, and very gentle passive motion of the arm could be performed, through a considerable angle, without pain, yet any attempts on her own part to move it produced great aggravation of her sufferings. As a result, no doubt, of habitual disuse, the muscles about the shoulder were much atrophied, and this caused a remarkable apparent prominence of the bony points, viz. the spine of the scapula, the acromion, the anterior border of the outer part of the clavicle, and the head of the humerus. The shoulder had an appearance that suggested at first sight the idea of dislocation.

On the 3rd of November, the patient being under the influence of chloroform,

Mr. Syme cauterized thoroughly the skin over the anterior and posterior aspects of the joint, rubbing a red-hot cautery iron freely backwards and forwards four or five times over each part. It had the effect of raising and rubbing off the cuticle, but did not char the skin. An hour afterwards the patient was suffering but little pain.

Nov. 4.—Said, with a smiling countenance, that she slept well last night, the first time for four months, and feels now no pain save that of the burns.

Nov. 5.—A poultice was applied yesterday ; the pain of the burn is now gone, and she feels *no pain at all.* Says that she has not only lost all pain, but also that the feeling of numbness is gone from the limb, and that she seems to have more power in it. The burned parts present a white sloughy appearance.

The poultice was continued till the sloughs separated, when simple cerate was substituted for it, with the view of retarding, rather than promoting cicatrization.

Nov. 12.—To-day she has been trying to lift the arm, and felt none of the old pain in the attempt.

Jan. 31, 1854.—She has to-day left the infirmary. She has for some time past been gradually acquiring more and more power in the limb ; she can move the arm backwards and forwards for a considerable extent, and even raise it slightly. The movements of the forearm are free ; there is no tenderness whatever about the shoulder. The return of the use of the limb has been accompanied with a restoration of the fullness of the muscles, so that there is now no difference between the contour of the two shoulders. She continues quite free from spontaneous pain.

I saw her again towards the end of May. She was still quite free from pain, and there remained only some stiffness about the joint that prevented her from raising the arm to the full extent.

CASE II.—*Disease of Shoulder-joint ; Actual Cautery ; Cure.*

Lily Kay, aet. 50, admitted the 23rd of March, 1854. Has generally enjoyed good health, except that for the last twelve years she has suffered inconvenience from what she supposed to be rheumatism in the right shoulder, characterized by shooting pain, occurring more especially when she attempted to lift anything. In January last the limb became completely disabled from increase of the pain, which now assumed a gnawing as well as a shooting character, and also began to be felt in the elbow-joint, and in the arm, forearm, and hand. At this time she first observed the existence of swelling about the shoulder-joint.

The pain continued to increase till the time of her admission into the infirmary, when it was exceedingly severe ; not constant, but frequently keeping

her awake at night. She was unable to raise the arm from the side, and had a sense of weakness in the limb, and some stiffness of the hand. There was considerable swelling about the shoulder-joint, which was tender on pressure, particularly at the anterior and posterior aspects. On the day of admission Mr. Syme applied the actual cautery freely over the anterior and posterior parts of the joint, the patient being under chloroform. From this time she lost the old pain entirely, or at least was uncertain whether that which she still felt was not altogether that of the burn ; and though the pain of the burn was considerable till the sloughs separated, yet it was much less distressing than the old pain, for which it was substituted, so that she slept much better than before the application of the cautery. The sloughs came away on the 1st of April, on which day she had a slight return of the old pain near the wrist, but it has not occurred again, and she is now (the 4th of April) quite easy. The swelling about the shoulder has almost entirely disappeared, and there is little, if any, tenderness ; the sores are granulating healthily.

April 14.—Continues quite easy.

She was discharged on the 27th of April ; I saw her about a month after, and she still continued free from pain.

Case III.—*Disease of Wrist-joint ; Actual Cautery ; Cure.*

Janet Archibald, aet. 32, admitted the 2nd of November, 1853. Rather a weakly subject. In October last she 'took a shivering', without any particular exposure to cold, and a pricking pain came on in the left wrist, which increased for a time, and was accompanied with swelling. She applied poultices medicated with acetate of lead, and under their use a great improvement had taken place at the end of five weeks, when she got fresh cold in it, as she says, and it became excessively painful ; the pain continued ever after till her admission, and although its extreme severity was then somewhat mitigated, yet it kept her awake a good deal at night ; it was partly dull and heavy, and partly of a shooting character, and extended down through the hand and fingers. There was also an occasional tingling sensation in the fingers, and a sense of unnatural weight in the limb. A great degree of swelling existed about the wrist-joint, particularly on the dorsal aspect, and this part when manipulated gave a feeling very like that of fluctuation, so that her medical attendant had been desirous to open what he had supposed a collection of matter there.

Mr. Syme regarded the condition of the wrist as almost hopeless, but as he thought suppuration had not yet occurred, he determined to give the limb a chance with the actual cautery, which he accordingly applied on the dorsal aspect in two lines, crossing one another over the articulation. The pain and

swelling both diminished greatly during the first four weeks after the cauterization; some aggravation of the symptoms then occurred for a time, but as the sore was still open, Mr. Syme thought it unnecessary to interfere further, and a gradual improvement afterwards took place, till at the time of her leaving the infirmary (the 14th of February, 1854) there was scarcely any swelling and very little pain.

I saw her again on the 10th of June; there was then no swelling whatever about the wrist, and no uneasiness except a painful feeling of weakness when she exerted it much.

Case IV.—*Disease between the Atlas and Axis; Actual Cautery applied with great benefit.*

Thomas Smith, aet. 27, admitted the 20th of June, 1854. Generally enjoyed good health till eighteen months ago, when a stiffness of the neck came on without any assignable cause, with pain when he turned round his head on the pillow; the pain increased greatly, and deprived him altogether of sleep for seven weeks, during which time he lost three stone in weight. There was severe pain in the head as well as in the neck, aggravated to an extreme degree by either nodding or turning of the head, particularly the latter, which, indeed, he at last never did without turning the rest of the body also. He applied to numerous medical men in Birmingham, where he lives; and blisters and caustic issues were repeatedly applied to the back of the neck, but never gave more than very slight and very transient relief, and he says that from the commencement of his complaint he never had one minute's freedom from pain, except during sleep, till he came here.

At this time he was, according to his own account, about as bad as he had been at all. His countenance wore a peculiar expression of mingled suffering and apprehension, as Mr. Syme expressed it. He complained of severe pain in the neck and head, aggravated by any sudden movement, so that there was a great constraint about all his actions. He always kept his head bolt upright except when in bed, and could neither lie down nor get up without supporting his head with his hands; he never turned his head without the rest of the body, but gentle nodding was not very painful. There was great swelling of the upper part of the neck, and he could only open his mouth a little way; deglutition was extremely difficult, and a remarkable prominence of the bodies of the upper cervical vertebrae was to be felt in the pharynx.

On the day after his admission, Mr. Syme applied the actual cautery over the spinous processes of the upper cervical vertebrae; the man was not under chloroform, and said he hardly knew whether the pain was greater even at the

moment than what he had experienced from caustic issues, and immediately afterwards he told us that he did not feel the pain of the burn at all. Next day he found less pain in moving the head, and in two or three days his countenance assumed a cheerful aspect. A steady daily improvement has since taken place in his symptoms, and at the present time (the 15th of July) he has no pain whatever when he sits at rest, and can also use strong and active exertion without uneasiness, and no longer requires to support his head in lying down or rising ; he can turn his head round pretty freely and look up to the ceiling, and it is only in sudden movements of the neck that he feels any pain at all. The swelling of the neck has greatly subsided, and he can open his jaws wide, and swallow with comparative facility. The sore on the neck is almost healed, and he talks of leaving the hospital in a few days as cured.

Remarks.—The above cases speak for themselves ; and I might add several others, that exemplify in an equally striking manner the beneficial effects of the actual cautery in certain forms of articular disease. It will be observed that it is by no means so painful a remedy as is generally supposed, and also that its good effects are more than can be attributed to the mere discharge of pus from the sore which it produces, seeing that a great improvement commonly occurs within a few hours of its application, and long before suppuration is established.

It is now many years since the use of this means of counter-irritation was introduced into Great Britain by Mr. Syme ; but although a constant series of successful cases have since continued to demonstrate its value to those who have witnessed his practice, yet I am satisfied that it has not hitherto been sufficiently generally appreciated. Case IV is an example of its efficacy against a most formidable disease, where caustic issues had been long tried in vain. I believe many limbs and lives have been sacrificed that might have been saved by the actual cautery, and by it alone ; and having been myself very strongly impressed with the importance of the subject, I should be truly glad if any surgeon who may have hitherto overlooked it, should be induced by the above report to inquire more closely into its merits.

ON AMPUTATION

[*Holmes's System of Surgery*, vol. iii, third edition. London, 1883.]

Part I

Amputation is often regarded as an opprobrium of the healing art. But while the human frame remains liable to derangement from accident or disease, the removal of hopelessly disordered parts, in the way most conducive to the safety and future comfort of the sufferer, must ever claim the best attention of the surgeon. Indeed, the progress of medical science, while furnishing the means of curing some affections once regarded as hopeless, and thus in one sense restricting the field for the application of amputation, has in another point of view extended that field, by improving the mode of operative procedure, and divesting it of much of its terror and danger ; so that whereas in former times the removal of a limb was only resorted to in cases of the most serious nature, it is now often practised when the unoffending member is merely a source of inconvenience.

It is instructive to trace the history of the improvement of this department of surgery.

Hippocrates (B.C. 430) recommended only a very rude kind of amputation, consisting of cutting through mortified limbs at some joint, 'care being taken not to wound any living parts.' [1]

On the other hand, Celsus, who seems to have lived at the commencement of the Christian era, advised that the removal of gangrenous limbs should be effected between the dead and living parts, and so as rather to take away some of the healthy textures than leave any that were diseased ; and as he interdicted amputating through an articulation, his operations must often have been performed entirely through sound tissues. He directed that the soft parts should be divided with a knife down to the bone, and then dissected up from it for some distance, so as to allow the saw to be applied at a higher level. The rough surface of the sawn bone was then to be smoothed off, and the soft parts, which, as he tells us, will be lax if this plan be pursued, were to be brought down so as to cover the end of the bone as much as possible. This method seems calculated to afford good results ; particularly as it appears probable from his writings that

[1] Hippocrates, *de Articulis*, p. 639 of the Sydenham Society's translation.

Celsus employed the ligature for arresting haemorrhage after amputation,[1] and dressed the stump in a manner favourable to the occurrence of primary union.

Archigenes, who practised in Rome shortly after the time of Celsus, paid special attention to the control of haemorrhage during the performance of the operation ; and appears to have been the first to employ for this purpose a tight band or fillet encircling the limb above the site of amputation. But while in this he did good service, he applied the red-hot iron to the surface of the stump and also neglected the dissection of the soft parts from the bone, advised by Celsus, though compensating to a certain extent for this omission by retracting the integuments before dividing them.[2]

Galen, who was in truth more of a physician than a surgeon, declined still more from the Celsian precepts, and reverting to the practice of Hippocrates, advised amputating through the dead tissues and applying the cautery to the

[1] On this interesting point in surgical history I am disposed to agree with the author of the article ' Amputation ' in Rees's *Cyclopaedia*, in opposition to the prevalent opinion that Celsus employed the ligature only in ordinary wounds, and used the actual cautery in amputations. The directions of Celsus regarding amputation are contained in his chapter on the treatment of gangrene, in which the only mention of haemorrhage is the statement that patients often die of it during the performance of the operation (*in ipso opere*), referring doubtless to profuse bleeding resulting from ignorance of the circulation of the blood, and of any means of controlling it in the limb. Certainly this expression is no proof that the cautery was used rather than the ligature ; for the former is the more speedy method of the two. Neither is the absence of allusion to the ligature in this passage any evidence against its employment after amputation ; for the argument would apply equally to the cautery, and no one doubts that one of these two means was used. Celsus, who is remarkable for his extremely concise style, leaves us to refer to his previous chapter on wounds, in which the subject of haemorrhage is very ably discussed. In slight cases pressure with dry lint, and a sponge wrung out of cold water, is recommended, or if this does not answer, lint steeped in vinegar is to be used ; but any portion of dressing retained in the wound is said to do mischief by causing inflammation ; and on the same principle caustics and other powerful styptics, though very efficient in arresting the bleeding, are prohibited because they produce a crust, which acts like a foreign body. In more severe cases the vessels are to be tied ; and finally, ' when the circumstances do not even admit of this,' the red-hot iron may be used as a last resort.

The only thing that seems to me to give any colour for doubt upon this subject, is the manner in which the ligature is described, ' venae quae sanguinem fundunt apprehendendae, circaque id quod ictum est duobus locis deligandae intercidendaeque sunt ' ; language which seems rather to apply to a partially divided blood-vessel than to one completely severed ; but as the context shows that the ligature, as used by Celsus, was applicable in the majority of cases, and to more vessels than one in the same wound, it can hardly be conceived possible that the practice was restricted to the very rare case of partial division.

Again, there can be little doubt that in drawing down the soft parts over the bone after amputation, Celsus aimed at primary union, the great advantages of which are strongly insisted on in the same admirable chapter on wounds ; but it is certain that he knew that the use of the cautery would have destroyed any chance of union by first intention.

One argument that has been urged on the other side is, that if he had employed the ligature in amputation, it would hardly have been neglected by his successors : but the slowness of the surgeons of the sixteenth and seventeenth centuries to adopt it, in spite of the strenuous advocacy of Paré, with all the advantages of a printed literature, show how little weight is to be attached to this objection. The utter neglect, during the Middle Ages, of the Celsian method of amputation, and of his simple mode of treating wounds, may also be mentioned as analogous cases.

[2] Sprengel's *History of Medicine*, French translation, vol. ii, p. 81, and vol. vii, p. 312.

residue of the mortified part ;[1] and for several centuries after his time either this method or others equally rude and often much more barbarous continued to be employed.

During the Middle Ages, the ligature, though used for ordinary wounds, was never thought of in amputation, and whatever may have been the practice of Celsus in this respect, there is no doubt that the great French surgeon Ambroise Paré, when he so applied it, in the middle of the sixteenth century, had all the merit of originality. But, though he urged its superiority over the cautery with able argument, supported by his extensive experience in both military and civil practice, yet his teaching failed for a long time to influence surgeons generally, either in his own country or in other parts of Europe.

The principal reason for this appears to have been that the fillet, which was the means still in use for controlling the bleeding during the operation, did not answer its purpose effectually even in the ablest hands : so that the dread of haemorrhage led most surgeons to prefer the cautery as a more expeditious method than the ligature. We even find Fabricius of Aquapendente repeating, in 1618, Galen's timid doctrine of the danger of amputating through living parts at all ;[2] and in 1633 the celebrated Fabricius Hildanus, though describing the ligature, states that the time which it occupies, and the consequent loss of blood, make it suitable only for the robust and plethoric, and declares that he ' cannot sufficiently extol the excellence ' of the *cauterium cultellare*, or red-hot knife, by which the orifices of the vessels were sealed while they were divided.[3]

In consequence of this same fear of bleeding, the great object at this period seems to have been to accomplish the work of severance of the limb as speedily as possible, and this was often done without any attempt whatever to provide a covering for the bone. Scultetus, in 1655, depicted the performance of amputation of the hand by chisel and mallet ; and Purmannus, in his *Chirurgia Curiosa*, written as late as 1696, mentions having seen legs removed by two different surgeons by modifications of a barbarous instrument of the Middle Ages, a sort of guillotine, ' which, by its great weight and sharpness, cuts at once the skin, flesh, and bones asunder ' ; but he states that it splintered the bone, and *therefore*, ' all things considered, the ancient way of cutting through the flesh with a knife, and through the bone with a saw, is more practicable, safe, and certain.'[4]

As an example of the ordinary practice of the seventeenth century may

[1] *Galeni ad Glauconem*, lib. ii, cap. xi.

[2] *Hieronymi Fabricii ab Aquapendente Opera Chirurgica*, pars i, cap. xcvi.

[3] ' Porro excellentiam hujus cauterii non satis extollere possum,' *Gul. Fabricii Hildani Opera omnia*, lib. de Gangraena et Sphacelo.

[4] Purmannus' *Chirurgia Curiosa*, English translation, book iii, chap. xii.

be mentioned that of Richard Wiseman, Sergeant-Surgeon to King Charles II. A fillet having been tightly applied, for the threefold purpose of checking haemorrhage, rendering the limb less sensitive by pressure on the nerves, and steadying the soft parts, which were retracted by an assistant, he carried a crooked knife by a single circular sweep down to the bone, which was divided with the saw at the same level, and the bleeding was arrested by the cautery, or some kind of styptic.[1]

Thus the mode of amputation employed by the father of British surgery only two centuries ago was precisely that used fifteen hundred years before by the Roman Archigenes. And very unsatisfactory were the results which it commonly afforded. The soft parts were insufficient, even in the first instance, to cover the end of the bone, which was accordingly cauterized, with the object of accelerating its inevitable exfoliation, and in the further progress of the case it tended to become more and more exposed by the contraction of the muscles; and even if the patient survived the protracted suppuration that ensued, he suffered more or less from the inconveniences of what has been called the sugar-loaf stump, being in the shape of a cone, the apex of which was formed by the prominent bone, covered either by a sore which refused to heal, or by a thin pellicle of cicatrix, very liable to abrasion.

A great step towards a better order of things was made in 1674 by the French surgeon Morel, in the invention of the tourniquet,[2] which though at first but a rude contrivance, being a stick passed beneath the fillet and turned round so as to twist it up to the requisite degree of tightness, furnished the basis for the greatly improved instrument devised in the early part of the following century by his distinguished countryman, J. L. Petit. This consisted essentially of two metallic plates, which could be separated from one another by means of

[1] The ligature, though known to Wiseman, seems not to have been adopted by him. After describing different modes of applying it, in a way that shows pretty clearly that he had not practised them, he writes, 'But the late discovery of the royal styptic hath rendered them of less use. But in the heat of fight it will be necessary to have your actual cautery always ready, for that will secure the bleeding arteries in a moment, and fortify the part against the future putrefaction.'—*Chirurgical Treatises*, book vi.

[2] English surgeons might dispute with the French the honour of the invention of the tourniquet. In a work written in 1678, published in 1679, entitled *Currus Triumphalis e Terebintho*, Mr. James Young, of Plymouth, gives an account of a similar contrivance, apparently produced independently by himself. He describes it as 'a wadd of hard linen cloth, or the like, inside the thigh, a little below the inguen; then, passing a towel round the member, knit the ends of it together, and with a battoon or bedstaff, or the like, twist it till it compress the wadd or boulster so very straight on the crural vessels that (the circulation being stopped in them) their bleeding, when divided by the incision, shall be scarce large enough to let him see where to apply his restrictives' (p. 30). Further on in the book he states that the same principle is applicable with advantage in amputations of the upper limb. But as he does not inform us how long he had used this expedient before he wrote the account of it, the credit of priority must of course be accorded to Morel.

a screw, so as to tighten a strap which was connected with them and also encircled the limb : and it is upon this principle that the ordinary screw tourniquet is still constructed. From this time forward, except in amputations performed near the trunk, haemorrhage during the operation ceased to be an object of dread, and surgeons were at liberty to consider other questions besides mere rapidity of execution.

The improver of the tourniquet, and our own great countryman Cheselden, seem to have conceived independently of each other the idea of performing amputation by ' double incision ' ; in which the skin and fat were first cut through by a circular sweep of the knife and retracted for about an inch, when the muscles and bone were divided as high as they were exposed.[1]

But this, though a great improvement, had only the effect of diminishing the cicatrix without covering the bone ; [2] and Louis, another eminent Parisian surgeon, believed that in the thigh the objects sought might be better attained by dividing all the soft parts at once, and sawing the bone at a higher level. In order to allow the muscles to contract freely when divided, he avoided the use of the tourniquet, and was the first to employ in its place digital compression of the femoral artery at the groin. He pointed out the important circumstance that the muscles on the posterior aspect of the thigh, being divided far from their origin at the pelvis, contract to a much greater extent than those at the anterior part of the limb, which are connected with the bone where they are cut ; and he showed that, the soft parts having been severed to the bone by a circular incision and drawn up with a linen retractor, the saw might be readily applied two and a half inches higher up, after the knife had been carried through the attachments of the anterior muscles.[3] This method was amputation by double incision on a different principle ; and though, in truth, a revival of the practice of Celsus, was not less valuable than the plan of Cheselden and Petit, and seems to have afforded results superior to theirs.[4]

Louis, however, was content if the stump when healed was free from conical

[1] It is difficult to determine to whom the priority belongs in this matter. Petit in his posthumous work states, ' Je suis le premier qui ait coupé les chairs en deux temps ' ; and also, 'J'ai imaginé de couper les chairs en deux temps ' ; and Dieffenbach, in his *Operative Surgery*, gives 1718 as the date of the introduction of the double incision by Petit. On the other hand, Cheselden as distinctly claims the original idea in the following passage in his notes to Gataker's translation of *Le Dran's Surgery* : ' The thing that led me to do this was what has too often happened—the necessity of cutting off the end of the stump the second time. This operation I proposed to my master when I was his apprentice ; but he treated it with neglect, though he lived afterwards to practise it when he had seen me perform it in the same hospital.' This proposal must have been made before 1711, when, at the age of twenty-two, he began to lecture on anatomy. '

[2] This is well illustrated by the drawing of a stump given by Cheselden in *Le Dran's Surgery*, for the purpose of showing the good effects of the double incision.

[3] *Mémoires de l'Académie de Chirurgie*, vol. ii, p. 286.

[4] Ibid., vol. iv, p. 60.

projection,[1] and did not aim at forming a complete covering for the bone. This was effectually done about a quarter of a century later by Alanson of Liverpool, by dissecting up the integuments for some distance and then dividing the muscles obliquely, so that they formed a hollow cone, in the apex of which the bone was sawn 'about three or four fingers' breadth higher than was usually done'. The effect of this was to 'fully cover the whole surface of the wound with the most perfect ease';[2] but in the hands of other surgeons the oblique division of the muscles proved to be a matter of considerable difficulty, and the object was accomplished as efficiently and more simply by Mr. Benjamin Bell, of Edinburgh,[3] and Mr. Hey, of Leeds, by a combination of the methods of Cheselden and Louis; or, as Mr. Hey expressed it, 'with a triple incision,'[4] in which the skin and fat were first divided circularly and dissected up for some distance, then the muscles were cut at a higher level, and these were retracted so as to permit the bone to be exposed and sawn considerably higher. Mr. Hey added the advice to cut the posterior muscles somewhat longer than the anterior, to compensate for their greater contraction; and thus towards the end of last century, 'the circular operation,' as it is termed, may be said to have been brought to perfection.

Meanwhile a different principle had been long before suggested and acted on. So early as 1678, Mr. James Young, of Plymouth, described 'a way of amputating large members, so as to be able to cure them *per symphysin* in three weeks, and without fouling and scaling the bone'. The directions given for this method, the 'first hints' of which he says he had 'from a very ingenious brother of ours, Mr. C. Lowdham of Exeter', are as follows: 'You are with the catling, or some long incision-knife, to raise (suppose it the leg) a flap of the membranous flesh covering the muscles of the calf, beginning below the place where you intend to make excision, and raising it thitherward of length enough to cover the stump; having so done, turn it back under the hand of him that gripes; and as soon as you have severed the member, bring this flap of cutaneous flesh over the stump, and fasten it to the edges thereof by four or five strong stitches.'[5] Eighteen years later, Verduin, a surgeon of Amsterdam, ignorant apparently of what Lowdham had done, provided like him a covering for the end of the stump from the calf; but, instead of cutting from below upwards, and only raising the integuments, he thrust a knife behind the bones at the part

[1] 'L'amputation la plus parfaite est, sans contredit, celle dans laquelle les chairs qui forment l'extrémité du moignon conservent assez de longueur pour se maintenir au niveau du bout de l'os.' Op. cit., vol. iv, p. 41.

[2] Alanson's *Practical Observations on Amputation*, 2nd edit., p. 16.

[3] Benjamin Bell's *System of Surgery*, 7th edit., vol. vii, p. 260.

[4] Hey's *Practical Observations*, 3rd edit., p. 527.

[5] James Young's *Currus Triumphalis e Terebintho*, p. 108. A copy of this interesting book exists in the library of the Royal Medical and Chirurgical Society of London.

where he intended to divide them, and cutting downwards formed a muscular flap, which he afterwards supported by an apparatus devised for the purpose of pressing the cut surfaces together so as to check bleeding without the use of either cautery or ligature.[1] This machine being complicated and unsatisfactory was rejected in 1750 by M. Garangeot,[2] who, substituting the ligature for it, but retaining in other respects the method of Verduin, brought amputation of the leg to the form in which it is still often practised at the present day.

The same principle was applied to the thigh, in 1739, by Ravaton, of Landau; but instead of one long flap he made two short ones. Having divided all the soft parts circularly, he thrust a knife down to the bone on the anterior aspect of the limb, a hand-breadth higher up, and cut down to the circular wound; and, having made a similar longitudinal incision behind, dissected up the square lateral flaps thus formed, and sawed the bone where it was exposed at their angle of union, and brought them together after tying the vessels.[3]

Vermale, surgeon to the Elector Palatine, soon afterwards formed the flaps more easily, and of a shape better adapted for union, by introducing a knife at the front of the limb and pushing it round the bone at one side, so as to make it emerge at the opposite point behind, and then cutting a flap of rounded form by carrying the knife in a curved manner downwards and outwards, the same process being repeated on the other side.[4]

The flap operation, performed either by cutting from without inwards or by transfixion, was occasionally employed by various surgeons in the latter half of last century; but found its most strenuous advocate in the late Mr. Liston, and at one time seemed likely to supersede the circular method altogether. Its great merit in those days of painful surgery was its facility and speed; for the flaps were cut with great rapidity, and when they were drawn up by the assistant, the bone was exposed with the utmost readiness at the part where it was desirable to divide it; whereas, in the circular operation, to dissect up the ring of integuments was a somewhat troublesome and tedious process, especially in a limb increasing in thickness upwards like the thigh, and the use of a retractor was often necessary, in order that the saw might be applied at a sufficiently high level.

As regards the immediate results of the two methods, the principal difference between them was that the flaps, when formed by transfixion, contained a large amount of muscle, while the circular mode furnished a covering chiefly from the integument. In this respect the flap operation was at first supposed to have

[1] *Mémoires de l'Académie de Chirurgie*, vol. ii, p. 244. [2] Ibid., p. 261.
[3] Ravaton's *Traité d'Armes à feu*, p. 405; also *Mémoires de l'Académie*, vol. ii, p. 251.
[4] *Le Dran's Surgery*, Gataker's translation, p. 431.

a great advantage, as providing a muscular cushion for the end of the stump. But this opinion was shaken by further experience. The muscular part of the covering, no longer discharging its normal physiological function, degenerates and dwindles, while the integument tends to become thicker and firmer, so that the ultimate results of the flap and circular operations present no material difference. On the other hand, at the time of the performance of the operation, the method by transfixion has the great disadvantage that the muscular element in the flap is almost always redundant, and has to be tucked back to permit the edges of the skin to be stitched together, the natural result being tension and confinement of discharges and consequent inflammatory disturbance. In the very case in which the flap operation was first employed, viz. in the upper part of the leg, the muscular mass proved very inconvenient from its redundancy when the calf was largely developed ; and even under more favourable circumstances the heavy and contractile flap was apt to shift from its position or to drag down the skin of the front of the leg, so as to stretch it on the cut end of the tibia, and induce ulceration. Hence Mr. Liston himself, so early as 1839, preferred in muscular subjects a short posterior flap and an anterior one of the same length, composed of integument only ; [1] and in the latter period of his practice he changed this for the following modification of the circular operation, which was also suggested independently by Mr. Syme, and was used by him for many years in all cases of amputation in this situation. The skin and fat are divided by two crescentic incisions with the convexity downwards, so as to form short antero-posterior flaps of the integument, which is then dissected up considerably higher than their angle of union, after which the operation is completed as in the ordinary circular method.[2] This plan gives essentially the same result as the circular mode, while the raising of the integument is facilitated, and its edges can be accurately adapted to each other without any of the puckering that occurred at the angles of the wound after the old operation ; and experience shows that when the soft parts have been divided in this way they are quite as favourably disposed for primary union as when cut more smoothly in the form of flaps.

In the lower part of the thigh also, the presence of the contractile element in the flaps was found to be injurious by increasing the disposition to protrusion of the bone, from the action of the powerful hamstring muscles, cut so far from their origin at the pelvis. Mr. Syme accordingly adapted his modification of the circular method to that situation ; [3] and I can testify to the sufficiency of the covering which it afforded.

[1] Liston's *Elements of Surgery*, 2nd edit., p. 786.
[2] Syme's *Principles of Surgery*, 5th edit., p. 168.
[3] Ibid., p. 170.

The longer time required for this operation than that by flap was rendered a matter of no moment by the discovery of anaesthesia in surgery, in the year 1846.[1] Independently of the relief from bodily and mental suffering procured by this great event, it must be regarded as an era in the history of amputation, of at least equal importance with the invention of the tourniquet ; because, pain being abolished during the operation, as well as dangerous haemorrhage, surgeons are now, in the great majority of cases, deprived of all excuse for sacrificing anything, either in plan or execution, to mere rapidity of performance, and are enabled to regard simply what will most promote the two great ultimate objects in amputation—safety to life, and usefulness of the stump.

With regard to the latter object, it was till lately an understood thing that the end of the stump was not adapted for bearing any part of the weight of the body. Being tender from the presence of the cicatrix, it was not allowed by the instrument-makers to touch the artificial limb at all ; the apparatus being applied partly to the sides of the stump, but chiefly to some bony prominence resting on the upper edge of the socket—the tuberosity of the ischium when the thigh is concerned, and in the leg the internal tuberosity of the tibia, the head of the fibula, and especially the lower border of the patella.

To this general rule, however, a striking exception was presented by the amputation at the ankle devised by Mr. Syme, in which the bones are divided just above the malleoli, where they present a broad surface for diffusing the pressure over the integument of the heel turned up to cover them, specially fitted by the character of its epidermic investment and subcutaneous fibro-adipose cushion for bearing the weight of the body, while the cicatrix lies well forward out of reach of pressure. The result is that the patient can stand on the end of the stump as on the natural sole ; and when the deficient spring of the arch of the foot is compensated by some elastic material contained in a very simple boot, the limb proves nearly as useful as in its normal condition.

Subsequent experience has shown that similar advantages may be attained to a greater or less degree in stumps formed by amputation higher up the limb. It is easy by proper management to ensure the cicatrix falling out of reach of compression by the end of the bone ; and the integument, though tender in the first instance, gradually acquires a brawny and callous character when subjected to regulated pressure, like the skin over the dorsal aspect of the cuboid bone in talipes varus, and thus becomes able to bear the whole or part of the weight of the body according to the breadth of the cut surface of the bone, and the consequent diffusion of the pressure. Indeed, stumps possessing these qualities were occasionally obtained as long ago as the time of Alanson, who, speaking

[1] See the essay 'On Anaesthetics' (printed in vol. i, p. 135).

of the condition of a patient on whom he had performed amputation above the ankle by posterior flap, says: 'He has been several voyages to sea, and done his business with great activity. He bears the pressure of the machine totally upon the end of the stump, and has not been troubled with the least excoriation or soreness.'[1] But it is easy to understand why such results were altogether exceptional so long as the covering for the ends of the bones was provided by a posterior flap, which, from the force of gravity and the preponderating power of the posterior muscles over those at the anterior aspect of the limb, must always tend to drop from its original position, and leave some part of the bone to be covered only by cicatrix. And independently of this, in the case of the leg, the tibia being covered in front merely by the skin, a scar placed anteriorly is much more likely to suffer from pressure against the bone than one situated posteriorly. The amputation of the ankle is, indeed, by posterior flap; but the full rounded cushion formed by the cup-shaped integument of the heel renders this an entirely exceptional case. It is plain, therefore, that with reference to fitness of the stump for bearing the weight of the body, preference should be given to an anterior flap, which moreover has the great advantage of allowing a dependent opening for the escape of discharge.

The recognition of the advantages of the anterior flap is due to the labours of two English surgeons, the late Mr. Teale, of Leeds, and Mr. Carden, of Worcester, working independently of each other, and proceeding by different methods. Mr. Teale, who had the priority in publication, formed a long anterior and short posterior flap in the following manner. Having ascertained by measurement the semi-circumference of the limb where the bone was to be divided, he first traced with pen and ink upon the skin four lines of that length; two longitudinal, extending downwards along the sides of the limb, and two transverse, of which one joined in front the lower ends of the longitudinal lines, while the other ran across behind from one longitudinal line to the other at the distance of a quarter of their length from their upper extremities. Two rectangular flaps of very unequal lengths being thus mapped out, he raised them, including the muscles as well as the integuments, by cutting from without inwards, and sawed the bone at their angle of union; then, after tying the vessels, he bent the long anterior flap upon itself, that it might 'form a kind of pouch for the end of the bone', turning up its lower edge to meet that of the short posterior flap, to which it was carefully adjusted and united by a few points of suture, some stitches being also introduced where the edges of skin met at the sides of the stump.[2]

Experience with this method has shown that in properly selected cases it gives admirable results; the patient being often able to rest his entire weight

[1] Alanson, *On Amputation*, p. 133.

[2] Teale, *On Amputation*, pp. 34 et seq.

upon the end of the stump ; and even where this is not fully the case, the distribution of the pressure between the end of the stump and the bony prominences which formerly alone sustained it greatly increases the comfort and steadiness of locomotion.

Nevertheless it must be admitted that Mr. Teale's operation has serious drawbacks. Precise accuracy of execution being essential to its success, it demands a degree of time and pains which, under ordinary circumstances, would certainly not be grudged, if really necessary, but which most surgeons would be glad to be saved, and which sometimes, as in the pressure of military practice, could not well be given. Again, the cut surface is more extensive than with ordinary modes of amputation, involving a larger number of vessels to secure, and also, under some conditions of healing, a more profuse suppuration. But the greatest objection to this method with a view to its general application is the high division of the bone which would frequently be required in order to form the long anterior flap. This defect is of course most marked when the limb is of considerable thickness at the seat of amputation, and shows itself in its most exaggerated form in the thigh of a muscular subject. Thus in a particular instance, where the development was by no means extraordinary, the dimensions were such that, supposing the anterior transverse incision made at the level of the upper border of the patella, it would have been necessary, in order to preserve Mr. Teale's proportions, to saw the bone eleven inches further up, or full five inches higher than if the modified circular operation had been performed. This would seriously have increased the danger, which is always greater the nearer the seat of amputation is to the trunk,[1] while, in case of recovery, the short stump would have been very inferior in usefulness on account of the slightness of the leverage it could have exerted in controlling the movements of an artificial limb.

The same disadvantage would often be experienced in applying the method to the leg. Near the ankle, indeed, where the limb is small and the anterior flap short in proportion, the operation is comparatively free from this objection. But if the circumstances of the case should render it necessary to amputate higher in the limb, the rapid increase of the thickness of the calf would necessitate a high division of the bone greatly out of proportion to the extent of the injury or disease of the soft parts. In a leg of about average development the amputation at Mr. Teale's seat of election, dividing the bones just below the calf, would require the integuments to be sound to the level of the tip of the internal malleolus. But if the skin happened to be unsound to a quarter of an inch

[1] This principle has been pithily expressed by Dieffenbach in the words ‘ zollweise steigt die Gefahr ’. (*Operative Chirurgie*, vol. ii, p. 822.)

above that level, the bones would have to be divided an inch higher ; and a difference of three-quarters of an inch in the skin would involve a loss of two inches of the bones ; and, again, an affection of the integuments implicating less than two inches above the tip of the malleolus would require a division of the bones full four inches above Teale's seat of election. And in the last-named situation, where the calf is thickest, the very long flap, consisting in the greater part of its breadth of skin alone, would be very liable to suffer from sloughing.

From considerations like these some of the stanchest advocates of Mr. Teale's method are now disposed to restrict it to the lower part of the leg and just above the knee, where, by turning to account the integument over the patella, which is not used in ordinary operations, the anterior flap may be made of the requisite length without specially high division of the bone.

Mr. Carden proceeded upon a much more simple plan, forming a rounded anterior flap of integument only, without any posterior flap, and retracting the soft parts somewhat from the bone before dividing it with the saw ; 'thus forming a flat-faced stump with a bonnet of integument to fall over it.'[1] This practice he began as early as 1846, nine years before Mr. Teale first employed his rectangular operation ; and though refraining from publication, he obtained from that time forward most admirable results, both in safety to life and the amount of pressure that could be borne by the end of the stump.

It was principally at the knee, where amputation had not previously been much practised, that Mr. Carden applied his principle. The operation at this situation is thus described by him. 'The operator, standing on the right side of the limb, seizes it between his left forefinger and thumb at the spots selected for the base of the flap, and enters the point of the knife close to his finger, bringing it round through skin and fat below the patella to the spot pressed by his thumb ; then turning the edge downwards at a right angle with the line of the limb, he passes it through to the spot where it first entered, cutting outwards through everything behind the bone. The flap is then reflected, and the remainder of the soft parts divided straight down to the bone : the muscles are then slightly cleared upwards and the saw is applied' through the bases of the condyles. 'Or the flap may be reflected first, and the knee examined, particularly if the operator be undetermined between resection and amputation. In amputating through the condyles, the patella is drawn down by flexing the knee to a right angle before dividing the soft parts in front of the bone ; or if that be inconvenient, the patella may be reflected downwards.'[2]

This operation, when contrasted with amputation in the lower third of the

[1] See *On Amputation by Single Flap*. By Richard Carden, F.R.C.S., &c., p. 6. This is a reprint of an article in the *British Medical Journal*, April 1864. [2] Op. cit., p. 6.

thigh, presents a remarkable combination of advantages. It is less serious in its immediate effects upon the system, because a considerably smaller portion of the body is removed, and also because, the limb being divided where it consists of little else than skin, bone, and tendons, fewer blood-vessels are cut than when the knife is carried through the highly vascular muscles of the thigh; the popliteal and one or two articular branches being, as a general rule, all that require attention, so that loss of blood is much diminished. In the further progress of the case the tendency to protrusion of the bone, which often causes inconvenience in amputation in the thigh, is rendered comparatively slight by the ample extent of the covering provided, and also by the circumstance that the divided hamstrings slip up into their sheaths, so that the posterior muscles have comparatively little power to produce retraction. The superiority of the operation is equally conspicuous as regards the ultimate usefulness of the stump, which from its great length has full command of the artificial limb, while its extremity is well calculated for sustaining pressure, both on account of the breadth of the cut surface of the bone divided through the condyles and from the character of the skin habituated to similar treatment in kneeling. Considering, therefore, that this procedure can be substituted for amputation of the thigh in the great majority of the cases both of injury and disease formerly supposed to demand it, 'Carden's operation' must be regarded as a great advance in surgery.

It is also of great value with reference to the general question of the best mode of amputating in the lower limb. It confirms completely the conclusion which was, indeed, obvious enough from theoretical considerations, that there is no special virtue in the rectangular shape of the flaps advised by Mr. Teale, but that the advantages claimed for his method may be attained by much more simple means.

Nevertheless to extend the method by anterior flap of skin alone to the thigh and leg, as advised by Mr. Carden, does not seem to me judicious. A flap of integument alone, sufficiently long to cover the entire diameter of the limb, must be liable to the risk of sloughing; and I cannot but think it wise, when the muscular element is available for the purpose, to follow Mr. Teale's example by including it in the composition of the flap. An operation thus intermediate between those of Carden and Teale, with a rounded muscular anterior flap somewhat shorter than Teale's, and compensating for its diminished length and for the absence of a posterior flap by retracting the muscles before applying the saw, was practised in the thigh by Mr. Spence, of Edinburgh, before Mr. Carden published, and yielded very good results.[1] But this operation involves as high

[1] *Edinburgh Monthly Journal*, November 1859.

a division of the bone as Mr. Teale's, and it therefore became an important question whether its advantages might not be attained by some method free from this objection. The essential object to be aimed at is that, while the covering for the bone shall be ample, the tender cicatrix shall be placed sufficiently far back on the end of the stump to be well out of the way of pressure between the end of the bone and the bottom of the socket of the artificial limb. And if, consistently with attaining this object, the anterior flap could be shortened and eked out with a short posterior flap, it is plain that in exact proportion to the extent to which this was done would be the length of bone gained, with corresponding diminution of danger and increase of usefulness of the stump. Now it fortunately happens, both in the calf of the leg and in the thigh, that the bone lies far forward among the muscles, so that even its posterior surface is considerably anterior in position to the longitudinal axis of the limb. Hence a flap as long as two-thirds of the diameter of the limb would ensure the scar being considerably behind the point of pressure ; while a posterior flap half as long as the anterior one would be sufficient to complete the covering. The posterior flap, being short, may be made of integument only, without any risk of sloughing, thus getting rid of the bulk, weight, and contractility of a posterior muscular flap. On the other hand, the anterior flap, being still somewhat lengthy, should be raised so as to contain a good deal of muscle, which will be useful not only by ensuring sufficient vascular supply, but also by increasing the thickness of the cushion below the bone ; while any tendency to retraction that it possesses (small compared with that of the posterior muscles) will be counteracted by the force of gravity, through which it will naturally tend to occupy its proper place.

Such was the plan of amputating which I ventured to recommend for the thigh and the calf in the first edition of this work, on theoretical grounds which subsequent experience has only tended to confirm. The details of the method, as applied to these two situations respectively, will be found described in subsequent pages.

Before considering the operations best adapted for particular cases of amputation, it will be well to allude in a general way to the necessary instruments, and the mode of using them.

The amputating knife should have a straight and strong back, and a sharp point, near which the edge should present a gentle convexity. In the old circular amputation, a curved knife with a blunt extremity was employed to divide the integument at one continuous sweep ; but as the modified operation is always preferable, in which the skin is cut in the form of short semilunar flaps, this somewhat clumsy implement may now be entirely dispensed with. For a flap operation performed by transfixion, the blade should be about half as long again

as the diameter of the limb ; but when the soft parts are cut from without inwards, a much shorter knife will answer the purpose, and should therefore be preferred, as the movements of the smaller instrument can be directed with greater precision and speed. For removing a finger or toe, something intermediate between the tapering bistoury often used in France and the old round-bellied English scalpel will be found to combine the advantages of both, without the inconveniences of either, being equally adapted for piercing and cutting.

In using the knife, the young practitioner will have to unlearn some of the habits he has acquired in anatomical study. The object being now simply to divide the resisting textures efficiently, the stroking and scratching movements of the dissecting room must be changed for a free sawing motion : and for this purpose the knife must be held firmly in the hand, instead of being kept in the feeble position best suited for the investigation of delicate structures.

There is another error to which the habits of dissection may lead, far more serious than a cramped and awkward use of the knife, viz. that of directing the edge of the instrument towards the skin in raising a flap of integument. Such a practice, necessary in anatomy, in order to leave the subcutaneous structures intact, will, if carried into amputation, most seriously endanger the vitality of the flap, which derives its supply of nourishment from vessels ramifying in the fat, and must perish if those vessels are extensively divided through scoring of the *tela adiposa*. I am satisfied that integument designed to form a covering for the stump is often made to slough for want of scrupulous attention to this simple point.

The skin should always be cut perpendicularly to its surface, for if it is bevelled off to a thin edge, it is not only unsuited in shape for adaptation with a view to primary union, but the margin may slough for lack of nutriment.

In transfixing a limb, the direction of the knife must of course be changed as it passes round the bone, in order that it may emerge at the opposite aspect ; but it is desirable that this should be done in a continuous manner ; for if the instrument be thrust in for a certain distance, and then partially withdrawn and made to follow a new track, the punctured wound first made may cause very troublesome haemorrhage, if a considerable arterial branch happen to be divided in it.

In passing the knife round a bony prominence, such as the shoulder, care must be taken to hold the limb in such a position as shall relax the parts that are to be pierced, otherwise what might be quite easy may prove impossible ; and in the latter part of the process, when the point of the knife is advancing in a greatly altered direction, it is important to keep the back rather than the edge directed outwards, in order to avoid cutting the base of the flap.

In amputating at a joint, if the tissues are healthy, the division of the soft parts completes the process, there being no need to take away the articular cartilage, which is almost as favourably circumstanced for healing as vascular structures. Thus, when a finger is removed at the metacarpo-phalangeal joint, the whole wound may unite by first intention ; or if suppuration occurs, the cartilage undergoes a change into granulations by a process so speedy as hardly to delay the cure.

The saw, for dividing the bone in other cases, should be broad-bladed, with a stout back, like the ' fine saw ' of the carpenter, and should have small but well-set teeth. In applying the instrument, its heel being placed upon the bone, previously cleared of soft parts by a circular sweep of the knife, it should in the first instance be drawn with firm pressure towards the operator, so as to make a groove which it will have no disposition to quit in the first forward stroke. The bone is thus cut precisely at the place desired.

The assistant who holds the limb must take care not to press it forcibly upwards, otherwise the saw will become locked ; nor must he draw it downwards to any great degree, or the bone will break and splinter towards the last. But the operator should always be so placed as to be able to control with his left hand the part which he removes. Should any projecting portion be left, it must be removed with a pair of bone-pliers, which may be substituted entirely for the saw when the bone is of very small size, as in the fingers. In using them, the flat surface should always be directed towards the parts that are to be preserved, as the other sides of the wedge-shaped blades crush the bone while they divide it.

The tenaculum, long universally employed for seizing the bleeding vessels in order to tie them, has been superseded by the catch-forceps, which, like the bone-pliers, were introduced into surgical practice by the late Mr. Liston. Besides being always more convenient, they have the great advantage of making the surgeon independent of an assistant in cases of emergency. The ligature should be tightly and securely tied, by reversing in the second half of the knot the relation that the ends of the thread had to one another in the former half, or, in the language of sailors, by making a ' reef-knot '. The larger arteries should be drawn a little way out of their sheaths, as the best means of avoiding nervous trunks and other unnecessary tissue. The principal veins also should be tied ; the dread of exciting phlebitis by such treatment having proved entirely groundless. As regards smaller vessels, the old rule was to tie only such as furnished a distinct pulsating stream. But as the catgut ligature with short-cut ends has none of the inconveniences of the long threads of silk or flax formerly employed, there is now no objection to tying mere oozing-points, however numerous ; and

this practice has the great advantage that it banishes all risk of reactionary haemorrhage.

The catgut, of course properly prepared to fit it for surgical purposes, should be used of as slender quality as will bear the strain of tying ; except in the case of advanced atheroma, when the finer kinds may be found to cut through the degenerated tissues of an arterial trunk, and a thicker sort must then be employed for the principal vessels. If the ligature cannot be made to hold when applied round the point of the forceps in the usual way, as when fibrous tissue is condensed by inflammatory infiltration, the difficulty may always be overcome by threading a fine curved needle with catgut with both ends long, and passing it so as to take a substantial hold of the tissues at the site of the bleeding-point, cutting off the needle, and tying the two pieces of gut one at each side. The bleeding vessel will be sure to be included in one of them.

Torsion is preferred by some surgeons ; but, though it is admirable for many wounds, particularly about the face, those who have tried both in amputation will, I think, agree that the ligature is more unfailing and on the average more expeditious.

In the second edition of this work I recommended a practice which I had adopted for some years with great advantage, viz. raising the limb into the vertical position and pressing it firmly from the extremity towards the trunk with the view of emptying it of venous blood, and then tightening as rapidly as possible a screw tourniquet, previously kept perfectly loose. The contrast between the ' almost bloodless ' division of the tissues under such circumstances and the gush of venous blood which attended the operation when the tourniquet had been applied in the horizontal or dependent position of the limb was extremely striking. Soon afterwards Professor Esmarch, of Kiel, published his bloodless method, which consisted of forcing the blood out of the limb by means of an elastic bandage applied continuously from the distal extremity to a point some distance above the site of the intended operation, and then applying another elastic band just above, to serve as a tourniquet and maintain the bloodless condition when the continuous bandage was removed. By these means the limb is rendered absolutely ex-sanguine at the seat of operation.

There can be no doubt of the great advantage of the upper elastic band, which follows up any yielding of the soft parts and maintains continuously a perfectly effective constriction ; whereas with the common tourniquet, if the operation was protracted, and especially if the tissues were unusually yielding through inflammatory or oedematous infiltration, the inelastic strap had to be further tightened again and again in consequence of recurrence of bleeding. Esmarch's elastic tourniquet has thus entirely superseded the old instrument.

But for emptying the limb of its blood the method of elevation seems to me preferable, if it is used in such a way as to obtain its full advantages, with a view to which it is essential to understand the *modus operandi*. Though I first employed elevation, as others had occasionally done before me, with the object merely of emptying the limb of its venous blood, I saw before long that much more than this was really done. If the elevated position was maintained for a sufficient length of time, the perfectly blanched appearance of the skin implied that arterioles as well as veins were emptied in a manner that could not be accounted for on merely hydraulic principles by the effect of gravity upon the blood ; and being led to inquire into the matter experimentally, I ascertained that when a limb is raised, the first effect of gravity in emptying and relaxing the veins is followed by a gradual contraction of the larger as well as smaller arteries of the limb under the influence of the vasomotor nervous system ; the effect reaching its maximum in about four minutes.[1] If, therefore, the limb is kept raised to the utmost for about that length of time, care being taken not to press upon any part containing a venous trunk, and the elastic tourniquet is then rapidly applied, a degree of bloodlessness of the site of operation is obtained which is practically as good as that of Esmarch's method, while it is free from two objections which attend the latter. One of these is referred to by Esmarch, viz. that it is inapplicable in case of putrid infiltration of the tissues, on account of the risk of forcing septic matter into the interstices of sound tissues ; and I may add that I should feel considerable hesitation in applying the continuous elastic bandage to a part affected with soft malignant tumour, fearing the possibility of the disease being diffused by the upward pressure through venous or lymphatic channels. The method by position, on the other hand, is applicable to all cases. The other objection to Esmarch's method which many surgeons have complained of, and which has induced some to abandon it, is a liability to reactionary haemorrhage. From this also the method by position is free. Esmarch's original elastic band, consisting of a tube of caoutchouc about as thick as the finger, or a somewhat thinner solid rod of the same material, is, I believe, the best for the thigh ; because, while it is exceedingly effective, the abrupt constriction which it produces cannot injure the nervous trunks, well protected as they are by an abundant padding of muscles. But in the case of the arm, where the soft parts are comparatively scanty in proportion to the bone, serious paralytic effects have followed the use of the elastic tourniquet in this form. These are, however, entirely avoided by employing for the upper limb, in accordance with Von Langenbeck's suggestion,

[1] See an Address on the Influence of Position on the Local Circulation, *British Medical Journal*, June 21, 1879 (reprinted in vol. i, p. 176).

a flat elastic bandage, the pressure of which is more diffused. The elastic tourniquet, whichever form is used, should be put well on the stretch, and wound quickly three or four times round the limb to ensure efficiency of its action. The elastic bandage is fixed by means of a pin ; the rod or tube by tying in a bow pieces of stout tape previously well secured to its extremities. This may be done very simply by tying the tape very tightly round the end of the tube or rod bent into a loop, which cannot escape from the grasp of the ligature.

The only inconvenience attending the elastic tourniquet as compared with the old instrument is that it cannot be relaxed and tightened at pleasure to show the bleeding-points, but must be removed once for all. In practice, however, this difficulty is overcome by searching for the principal arteries in the places indicated by anatomical knowledge, and, when these have been secured, tying all points from which any venous blood oozes, by which means the vein and its accompanying artery will be both included. When this has been done, it will often be found that not a single vessel requires attention when the constricting band has been removed. But to guard against the chance of any having escaped notice, the main artery of the limb must be subjected to digital compression.

The strength of the assistant on whom this duty devolves is often early exhausted by unnecessary exertion ; for the current through an artery lying over a bone, or some other resisting texture, is completely arrested by a very moderate amount of pressure directed exactly to the proper part.

A stump after amputation is dressed on the same general principles as other wounds. When there is much tendency to muscular contraction with its attendant risk of protrusion of the bone, as in the lower part of the thigh, this disposition is greatly checked and repose of the stump promoted by a bandage applied smoothly and moderately firmly from above downwards, while an assistant draws down the soft parts. In the thigh and also in the leg great advantage is derived from bandaging upon the posterior surface of the stump outside the dressing a trough of Gooch's splint on which the stump rests smoothly, being rendered independent of movement or irregularity of the pillow. The end of the stump should not be much raised, as too great elevation interferes with free discharge, and increases through gravity the tendency to retraction of the soft parts.

Amputations in the Upper Extremity

The upper limb, independently of its smaller size, and the consequent less shock to the system from the operation, is more favourably circumstanced for amputation than the lower, in consequence, apparently, of its possessing a better

vascular supply and superior vital power. Thus, it is a more serious thing to amputate a toe than a finger, and to take away the arm at the shoulder-joint is a much safer proceeding than to cut off a leg below the knee, even though a larger wound be inflicted, and a larger portion of the body removed, in the former case than in the latter. The more advanced in life the patient is, the more do these differences show themselves. But if circumstances admit of the septic element being effectually excluded, such considerations have comparatively little of the weight formerly attached to them.

The particular amputations in the upper extremity will be most conveniently considered in the order in which they occur from below upwards. The distal phalanges, though very liable to injury and disease, rarely require amputation ; for the removal of crushed portions of bone in the former case, or exfoliation in the latter, will generally leave a useful end to the finger. If it be wished, the phalanx may be readily taken away by opening the joint across its dorsal aspect, and, after getting the knife round the base of the bone, forming a palmar flap, by cutting from within outwards. Or the palmar flap may be first cut by transfixion ; and this being held up by an assistant, the operation is completed by cutting straight through the articulation. If the whole distal phalanx be crushed, amputation through the second phalanx will be best performed by cutting from without inwards two rounded lateral or antero-posterior flaps, and dividing the bone with pliers.

Removal of the entire finger is generally preferable to leaving the first phalanx by itself, which, besides being unseemly, would be a mere incumbrance, except in the index-finger ; and even there it is of service only in some few handicrafts. For the middle, or the ring-finger, the operation is best performed according to the following definite rule. The adjoining fingers being held aside by an assistant, the surgeon cuts from the prominence of the knuckle in a straight line towards the middle of the web on one side ; but, just before reaching the web, carries the knife inwards to the fold between the finger and the palm, and, after making a similar incision on the other side, accomplishes the disarticulation. The edges of the skin will be found to meet exactly on approximation of the adjoining fingers, which should be kept tied in that position, to avoid disturbing the process of union. Remarkably little deformity results from this operation, so that removal of the head of the metacarpal bone for the sake of appearance is quite uncalled for. If, however, it is at any time necessary on other grounds to take away a portion of the metacarpal bone, this can be readily done by the same method, except that the incisions are made to start from the place on the back of the hand where the bone is to be divided by the cutting-pliers.

The index-finger may be removed in a similar manner, care being taken, in

making the incision on the side next the thumb, to carry the knife from the point of the knuckle in a longitudinal direction to near the level of the web between the fingers, before sloping it off towards the palm, otherwise the flap will be insufficient to cover the raw surface. A preferable method, however, is to make dorsal and palmar flaps of rounded form, by cutting from the web between the fingers to a point on the opposite side of the articulation at a sufficiently high level to allow the end of the metacarpal bone to be taken off obliquely with pliers, so as to get rid of what would cause an unseemly prominence. But if it be necessary to remove a considerable portion of the metacarpal bone, the former method, with the dorsal part of the incision extended upwards, will be the best.

Similar rules apply to the little finger ; and, in cases requiring it, the whole metacarpal bone may be removed, by commencing the incision a little above the articulation with the *os unciforme*, so as to give space for dividing the ligaments after clearing the bone of the muscles which surround it.

Any portion of the thumb is valuable for opposition to the fingers ; but, if necessary, the whole of it may be taken away by cutting in a curve, with the convexity downwards, from the web connecting it with the forefinger to the opposite side of the joint, both on the dorsal and palmar aspects, raising the rounded flaps, and disarticulating. The whole metacarpal bone may be removed along with the thumb on a similar plan, by entering the knife a little above the articulation with the trapezium, and cutting first longitudinally, and then with a gentle curve to the web, on each side of the bone, then dissecting up the flaps, and dividing the ligaments of the joint.[1] This operation has been often performed for tumour of the metacarpal bone ; but from a case published by Mr. Syme, it would appear that under such circumstances a useful thumb may be preserved by excising the bone affected.[2]

The thumb alone or a single finger, being far more useful than any substitute should always be retained if possible in cases of injury ; an artificial hand being afterwards used, provided with a claw, against which the single digit left may be pressed so as to hold objects firmly.

Amputation at the wrist-joint may be performed by cutting across the back of the wrist from one styloid process to the other, in a line presenting a slight concavity downwards, in accordance with the form of the articulation, opening the joint on its dorsal aspect, then shaping a rounded flap in the palm, raising

[1] For removing the thumb or little finger with the metacarpal bone, other modes of operating, somewhat more rapid, but in other respects disadvantageous even when applicable, were recommended before the introduction of anaesthesia. At present, it appears only necessary to mention such as are calculated to give the best results.

[2] *Observations in Clinical Surgery*, p. 38.

it to the joint, and disarticulating. Another method is to cut the palmar flap from within outwards after disarticulation ; but the prominence of the pisiform bone prevents this from being satisfactorily accomplished.

Amputation in the forearm may be performed by antero-posterior flaps. In front, where the muscles are in larger amount, transfixion may be adopted ; but behind, the presence of the two bones prevents this, except near the wrist, where it may be effected, provided the soft parts have their natural laxity, by pinching up the skin, and passing the knife as close to the radius and ulna as possible, when, after the integument has fallen back to its usual position, the extremities of the wound will be placed so far forward that the knife can be introduced through them in forming the anterior flap. But it is probably always well to cut the dorsal flap from without inwards, and to raise it so that it shall consist chiefly of integument, in order that redundancy of muscle and consequent tension may be avoided. The surgeon standing on the (patient's) left side of the limb, and holding it with the dorsal surface towards him, enters the knife a little to the palmar side of the bone that is the further from him, and cuts through the skin and fat so as to shape a rounded dorsal flap, terminating the incision a little to the palmar side of the nearer bone, where he at once pushes in the point of the knife, so that it may pass in front of the bones and emerge at the place where the operation was commenced, and cuts a fleshy palmar flap from within outwards. He then dissects up the dorsal flap ; and the soft parts being drawn back by an assistant, clears both bones thoroughly about three-quarters of an inch higher up, and applies the saw. The interosseous artery, which is apt to retract beside the unyielding interosseous membrane, must always be secured as well as the radial and ulnar trunks ; and if the median or ulnar nerve is exposed in the palmar flap, it should be shortened with scissors, to prevent the occurrence of painful symptoms as the stump heals.

There is no objection to amputation at the elbow-joint, in cases adapted for it. The most eligible plan is to cut a large anterior flap from within outwards, after transfixing the partially extended limb in front of the joint, bearing in mind that the line of the articulation is oblique to the axis of the humerus, and is considerably further below the internal than the external condyle. The flap being then held up by an assistant, the points of transfixion are connected posteriorly by a semicircular stroke of the knife, which, besides dividing the integument, probably detaches the radius, and a few touches with the point of the instrument will sever the connexions of the ulna. The assistant should keep the skin of the back of the arm drawn upwards during the operation.

Amputation of the arm presents a good example of the double-flap operation by transfixion. The point of the knife being entered at one side of the limb,

avoiding the site of the brachial vessels and nerves, is pushed on in front of the bone ; and then, by slightly raising the handle, is made to emerge at a place exactly opposite. The anterior flap is then cut with a brisk sawing movement of the instrument, which is first directed longitudinally for a short distance, and then turned gradually towards the surface, and brought out perpendicularly to the integument. The flap is now lightly raised by the assistant, without any traction, for this would interfere with transfixion behind the bone, which is effected through the extremities of the wound already made, and the posterior flap is cut like the anterior. The assistant now retracts the flaps firmly, when a circular sweep of the knife exposes the bone about an inch above the angle of union of the flaps, and another similar turn of the instrument prepares it for the application of the saw. The edges of the wound meet accurately when brought together, producing a symmetrically rounded stump. But when the muscles are largely developed, it is well to avoid the inconvenience occasioned by their redundancy, by cutting the flaps from without inwards, or by employing the modified circular method.

Amputation at the shoulder-joint is an operation which yields very satisfactory results, as was strikingly shown by the experience of the late Baron Larrey, who, during the wars of the first Napoleon, saved ninety out of a hundred cases, in spite of the very unfavourable circumstances of military practice.[1]

Of the various methods that have been proposed, that of Lisfranc is the most expeditious. The arm being raised so as to relax the deltoid, the point of a long-bladed knife is introduced about midway between the coracoid and acromion processes, and thrust round the outer side of the joint till it comes out within the posterior fold of the axilla (or, if the left limb be the subject of operation, the direction of transfixion is reversed), when a large muscular external flap is rapidly cut ; and this being held up by an assistant, and the arm drawn downwards and forwards, the joint is opened by cutting firmly upon the head of the bone,[2] which is then raised from its socket so that the knife may be passed round it, and carried downwards along the inner surface of its neck and shaft, followed by the other hand of the assistant, which grasps the tissues that lie between the track of the instrument and the axilla, so as to prevent bleeding from the main artery, when it is divided in the completion of the short internal flap.

This operation, however, is rarely available in practice. Its satisfactory performance requires the leverage of the humerus, which is generally broken in

[1] *Mémoire de Chirurgie militaire*, par le baron D. J. Larrey, tome iv, p. 434.

[2] Strictly speaking, this is Dupuytren's modification of the method of Lisfranc, who depressed the arm at the commencement of the operation, and opened the joint during the transfixion ; but this was a less easy proceeding, though shorter by a few seconds in very expert hands.

cases of injury demanding removal of the limb, in which also the parts necessary for the large external flap are often encroached on ; and in tumour of the bone, which is the other affection that most frequently calls for amputation in this situation, transfixion becomes inadmissible.

On the other hand, Larrey's mode of operating, by lateral flaps of equal size, proved almost always applicable in his cases of gunshot-wound, while it was as secure against haemorrhage as that of Lisfranc. Thrusting the point of a knife of moderate length down to the bone immediately below the acromion process, Larrey first made a longitudinal incision about two inches in length, from the extremity of which he cut in a curved line at each side of the limb to the fold of the axilla ; then dissected up the muscular flaps so as to expose the articulation completely, a finger of an assistant being placed upon the divided circumflex artery ; and, having severed the connexions of the head of the humerus, passed the knife round it, and kept the instrument close to the inner side of the bone, till, turning the edge towards the surface, he last of all divided transversely the tissues intervening between the axillary folds, containing the artery, previously commanded by the hand of the assistant following the knife.[1]

This operation is improved by dividing the structures between the folds of the axilla obliquely, as part of the internal flap, the lower portion of which is reserved to be cut from within outwards, at the conclusion of the operation : the result being two precisely similar semilunar flaps, meeting above at the acromion and below at the posterior fold of the axilla, adapted for immediate union throughout their length, and presenting as small a wound as is consistent with an efficient covering.

When the bone is broken near the joint, it will be found useful to adopt Mr. Syme's expedient of introducing the finger into a longitudinal wound in the capsule, for the purpose of drawing down the head of the bone so as to gain access to its attachments. In some cases of tumour it may be necessary to raise all the soft parts, including the axillary vessels, from without inwards ; when haemorrhage must be restrained by compression of the subclavian artery over the first rib, by the thumb of an assistant pressed down behind the collar-bone.

Sometimes it may be best to make a large superior flap, cut from without inwards, containing the whole width and chief length of the deltoid muscle ; but circumstances will often arise in which no regular rule can be followed, and the parts that happen to be sound must be turned to the best advantage, accord-

[1] During one period of his practice, he formed the lower parts of the flaps by transfixing from the end of the longitudinal incision to the borders of the axilla, and cutting from within outwards ; but the method given in the text is that to which he ultimately gave the preference. See Larrey's *Clinique chirurgicale*, 1829, p. 563.

ing to the judgement of the operator. Even when a large raw surface is left, the granulating process will complete the cure, as is well illustrated by some of Larrey's cases, which terminated satisfactorily after extensive loss of the soft parts of the shoulder and removal of portions of the scapula.

Amputations in the Lower Extremity

The distal phalanx of the great toe may be removed in the same way as that of a finger. When one of the smaller toes is in a condition requiring amputation at all, it should be taken away entirely, since any portion left would be likely to prove inconvenient from being tilted upwards. The operation is exactly similar to that for a finger ; but it must be borne in mind that the articulation with the metatarsal bone, which is the starting-point for the incisions, is much further behind the web than the corresponding joint in the hand, in proportion to the size of the digit.

When the whole great toe is removed, or the little toe, the prominent part of the head of the metatarsal bone must be cut off by an oblique application of the bone-pliers, as it would prove inconvenient if left. The longitudinal part of the incision in the soft parts should be placed on the dorsum of the foot, to avoid the inconvenience that might arise from pressure on a scar at the lateral aspect. In amputating the great or little toe, together with the whole metatarsal bone, it is best to proceed as in the analogous operation for the little finger, the incision being commenced on the dorsum of the foot, about a quarter of an inch behind the articulation with the tarsus, and carried longitudinally to near the metatarso-phalangeal joint, where it bifurcates to embrace the root of the toe. The knife, which should be a strong one, is then applied with a short sawing action close to the metatarsal bone and its articulation with the toe, so as to clear them completely ; and the ligamentous attachments of the base of the bone are lastly divided with the point of the instrument. In the case of the great toe, it is especially important to keep the knife well under command, and avoid thrusting its point deeply into the sole ; for this, besides inflicting unnecessary punctures, may wound the plantar artery at a part difficult of access. This mode of removing the great or little toe and its metatarsal bone, though not so rapid as that of dissecting up a flap from the side of the foot, then cutting between the toe to be removed and the adjoining one, and disarticulating, has the great advantage of avoiding any scar in the sole.

If more metatarsal bones than one require removal, the incision must be begun in the same way, but made to include the roots of all the toes concerned, so as to form a dorsal and a plantar flap ; and even in case of caries in the articulation between the tarsus and metatarsus at one side, a useful foot may be left

after taking away the bones affected, by means of a similar incision commenced further back.

The separation of the whole metatarsus from the tarsus is an operation seldom called for ; but it is evident, from the account given by the late Mr. Hey, of Leeds,[1] who introduced it, that it affords excellent results. When the state of the soft parts permits, the ends of the exposed tarsal bones should be covered with a long flap from the sole, turned up to unite with the dorsal integument, cut very short ; so that the cicatrix, being on the upper part of the foot, may be out of the way both of pressure in walking and of contact with objects in front of it. In performing the operation, it must be remembered that the tarso-metatarsal articulations are not in a regular line, but that the base of the second metatarsal bone is locked between the first and third cuneiform bones, of which the former is the more prominent, and is connected laterally with the second metatarsal by a very strong interosseous ligament. To divide this ligament, Lisfranc adopted the plan of thrusting an amputating knife obliquely downwards and backwards between the first and second metatarsal bones into the substance of the sole, the tissues of which served as a fulcrum, supporting the point of the instrument, when its edge was urged forcibly between the bases of the bones by pushing the handle backwards. This, however, is a needlessly rough proceeding ; for by pressing firmly back between the bases of the bones a strong and short knife, such as ought to be used for the rest of the operation, the ligament may be cut without difficulty ; after which all the articulations are readily separated by scratching through the dorsal and other ligaments with the point of the knife, while the metatarsus is strongly depressed.

The secret of facility in the operation lies in hitting the line of the articulations ; but this is readily enough done by finding first the joints of the first and fifth metatarsal bones, and bearing in mind that the others lie in a line between them, slightly convex forwards, interrupted by the recession of the second bone. The prominence of the base of the fifth metatarsal indicates the situation of its joint, and, if the parts be in a natural condition, the articulation of the first metatarsal with the first cuneiform can also be felt. Should inflammatory thickening obscure the position of the latter, it might be well to measure the distance of the corresponding joint from the internal malleolus on the sound foot ; or assistance may be derived from the circumstance that the joint lies midway between the malleolus and the metatarso-phalangeal articulation.

These points having been precisely ascertained, the surgeon grasps the fore part of the sole with his left hand, placing the tip of the forefinger at one of the joints, and the thumb at the other, to mark their position, and cuts firmly across

[1] Hey's *Observations*, p. 555.

the dorsum of the foot in a line slightly convex forwards, a little anterior to the articulations, taking care that the incision commences and ends fairly in the sole. He then opens the joints of the first and fifth metatarsal bones, so as to ensure finding the line of the articulations afterwards, and next shapes a long plantar flap by an incision extending from the extremities of that already made along the sides of the foot and roots of the toes, dissects up the flap from the bones, and completes the disarticulation in the manner above described.

When the anterior part of the sole is unsound, a shorter plantar flap and a proportionately longer dorsal one may be made, as recommended by Sir Astley Cooper.[1]

Sometimes the proceeding may be greatly simplified by sawing through the metatarsal bones a little anterior to their bases, and so avoiding disarticulation altogether. This method would probably have another advantage, from making the stump of the foot longer and therefore a more effectual lever for opposing the muscles which act upon the calcaneum through the tendo Achillis ; for experience has shown that when the foot is much shortened, the heel is apt to be drawn up, so as to cause the end of the stump to point more and more towards the ground, producing lameness or entire inability to walk. This has been noticed especially after Chopart's amputation through the tarsus, which is consequently an undesirable operation, even in cases of injury : while in caries it is further objectionable, because the part of the tarsus left behind, though apparently sound at the time, may become affected with the same disease at a later period.

If it be wished, however, Chopart's operation may be performed on the same principle as Hey's, by making a very short dorsal flap, and a plantar one reaching to the balls of the toes, to cover the exposed anterior surfaces of the astragalus and os calcis. The articulation between them and the navicular and cuboid bones will be found in a line running across the foot, through a point midway between the external malleolus and the base of the fifth metatarsal bone.

In the amputation at the ankle devised by Mr. Syme, the bones of the leg are divided just above the bases of the malleoli, a covering for the osseous surfaces being provided from the integument of the heel ; the result being a stump admirably fitted for bearing the weight of the body. At the same time, the parts likely to originate carious disease are completely got rid of ; so that this operation is calculated to supersede entirely that of Chopart, besides taking the place of amputation of the leg in the majority of the cases formerly supposed to demand it.

The operation should be performed as follows. Provision being made against

[1] *Surgical Lectures*, edited by Tyrrell, vol. ii, p. 432.

haemorrhage by the pressure of the thumb and finger of an assistant, placed respectively on the middle of the fore part of the limb and behind the tibia, about two inches above the joint, so as to control the anterior and posterior tibial arteries, or by an elastic tourniquet above the knee, and the foot being held at right angles to the leg, the surgeon puts his left hand behind the heel, with the finger and thumb on the places where the incisions are to commence and terminate ; these being the tip of the external malleolus and the point exactly opposite on the inner side, i.e. not at the tip of the internal malleolus, but considerably below and behind it. With a knife, short and strong both in blade and handle, he now cuts down to the bone across the sole, from one of these points to the other, in a plane either vertical or sloping slightly towards the heel when that part is unusually prominent ; and then, extending the foot, joins the horns of this incision by another running as straight as possible across the front of the ankle. He next dissects up the posterior flap from the os calcis, keeping the edge of the knife close to the bone with the guidance of the left thumb-nail, till the point of the calcaneum is fairly turned, when he proceeds to open the joint in front, divides each lateral ligament with a stroke of the knife applied between the malleolus and astragalus, and completes the removal of the foot by severing the tendo Achillis. He then prepares the bones of the leg for the application of the saw ; taking care, when cutting behind the tibia, to keep close to its surface, from which the posterior tibial artery is separated only by a little loose cellular tissue ; and lastly, he takes off the malleoli along with a slice of the intervening part of the tibia, sawing exactly perpendicularly to the axis of the limb—that is to say, directing the saw vertically and transversely while the leg is kept horizontal.

It is a common mistake to make the inner end of the incision at the internal malleolus, instead of opposite the extremity of the outer one. This has two bad effects : it renders the flap unsymmetrical, and, what is far worse, it makes it unnecessarily long, and thus introduces an element of difficulty and risk into an easy and safe operation. For when the incision is carried forwards into the hollow of the foot, it becomes a most troublesome task to turn back the integument over the prominence of the heel ; and the knife being thrust the operator knows not where, the subcutaneous tissue containing the vessels on which the skin depends for its nourishment is punctured and scored, and perhaps the point of the instrument itself appears occasionally through the skin itself, while the flap is subjected to violent wrenching in the effort to draw it back over the bony projection. Under such a combination of unfavourable circumstances, it is but natural that it should slough.

On the other hand, when the flap has been made as above directed, in

accordance with the latest recommendations of the author of the operation,[1] it applies itself with perfect uniformity to the surface it is designed to cover, and has no disposition to shift to one side in the after progress of the case ; and every stroke of the knife by which it is raised being made under the eye of the surgeon, without any forcible traction, it is as little liable to slough as any other portion of integument with an equally broad base and an equally rich vascular supply. Even the integrity of the posterior tibial artery, though desirable, is by no means essential, provided the rest of the subcutaneous tissue has been left uninjured. Many persons, in discussing the merits of this operation, seem to assume as an axiom that sloughing of the flap must occasionally take place ; but I am persuaded from very extensive experience that, if the skin of the heel be sound, such an occurrence will always be the fault of the surgeon.

Hence the various modifications of the original method that have been suggested, though commonly discussed chiefly with reference to a fear of sloughing, must be judged of entirely on other grounds. Thus the plan introduced by the late Dr. Richard Mackenzie, of Edinburgh, of making the base of the flap at the inner side, that it may have a more free supply of blood from the posterior tibial artery, is not to be regarded as a substitute for the simpler method of a posterior flap ; yet it proves useful in case of unsoundness of the integument on the outer side of the heel ; and it is probable that an external flap might be made with equal advantage if the internal aspect of the limb were affected. At the same time it may be worth while to remark that the mere presence of sinuses at either side is no ground for deviating from the original procedure ; and, further, that no degree of complication of sinuous tracks ought to induce the surgeon to amputate in the leg and deprive his patient of the greatly superior stump afforded by Mr. Syme's amputation.

The operation of the late Professor Pirogoff, of Petersburg, in which the posterior part of the os calcis is sawn off and turned up as part of the flap, to unite with the cut end of the tibia, has the disadvantage in cases of caries that it entails a risk of recurrence of disease in the portion of the calcaneum remaining. It is also more complicated than Mr. Syme's method, from the necessity of accurate adjustment of the osseous surfaces, with a view to the best position for the posterior flap. For this purpose both bones are cut obliquely ; the tibia in a plane looking somewhat backwards as well as downwards, and the os calcis in one that is directed somewhat upwards as well as forwards ; so that when the cut surfaces are applied to each other, the dense plantar integument covering the lower part of the calcaneum is presented downwards for supporting the weight of the body, rather than the thin skin over the posterior aspect

[1] See Mr. Syme's Clinical Lectures in the *Lancet*, 1854.

of the bone. If these points are attended to, Pirogoff's amputation gives a thoroughly useful stump in cases of injury. But I am not aware that it has any advantages over that provided by Syme's operation, and the increased length of the stump which it produces is rather objectionable than otherwise; for with the original operation, the space afforded for the artificial foot is not more than the maker finds convenient.

When the ankle-joint is affected with caries, the saw should be applied at a higher level than usual to the tibia and fibula, and the vertical articular surfaces by which the joint is continued upwards between those bones should be removed with cutting pliers, to guard against recurrence of disease in that situation.

In cases which do not admit of Mr. Syme's operation, amputation immediately above the ankle should be performed if possible, in preference to that at 'the seat of election', a little below the knee; for, although the use of the knee-joint may be retained even with a very short stump, the longer one gives greater command over the artificial limb, and the operation involves less risk to life.

Different methods may here be employed. One mode is to make a short semilunar anterior flap cut from without inwards, and a large posterior one formed by transfixing behind the bones and cutting downwards and outwards, the saw being applied a little above the bases of the flaps; or antero-posterior skin flaps of equal length may be made, and the bones divided somewhat higher up. Or again, the modified circular operation [1] is applicable in this situation.

But the method by longer anterior flap is greatly to be preferred to any other, on account of the excellent covering it affords, with the cicatrix out of the way of pressure, enabling the stump to sustain the whole or a considerable part of the weight of the body on its extremity. The principles on which the operation should be performed have been already fully discussed in former pages,[2] but a modification of the plan there indicated is called for on account of the difficulty of retracting the soft parts from the bones. This arises especially from the intimate attachment of the muscles to the fibula; but if these are divided through an extension upwards of the outer longitudinal incision, no difficulty is experienced, unless the tissues are condensed by inflammatory thickening, in effecting retraction of the remaining soft parts from the tibia without dividing the skin at the inner side to a higher level than the typical operation demands. Another point requiring special attention in the leg, as compared with the thigh, is the raising of the anterior flap. The anterior tibial artery, on which the flap depends for its nutrition, lies close to the inter-

[1] See p. 385.

[2] See pp. 387 et seq.

osseous membrane, and would be very liable to be punctured during the dissection if we did not follow Mr. Teale's advice in conducting it. He pointed out that in consequence of the looseness of the cellular connexions of the interosseous membrane, there is no difficulty in separating the parts in front from its surface with the finger-tip, while dividing with the knife the attachments of the muscles to the bones.[1] In this way, the vessel is secured from any chance of injury.

Immediately above the ankle the operation is performed as follows. The diameter of the limb having been ascertained by spanning it, a straight longitudinal incision of that length is made at the inner side of the leg, and on the outer aspect another similar incision directly over the fibula and extending about an inch higher up. The lower ends of these incisions are connected by cutting across the front of the limb in a direction transverse in the main, but rounded off where it joins the lateral lines. The knife is next carried round the back of the limb to the bones from the upper end of the internal incision to a point exactly opposite on the outer side, which will be about an inch below the upper end of the outer incision ; the instrument being carried in a line slightly convex downwards, so as to form a very short posterior flap. The anterior flap is then raised in the manner above mentioned, including everything in front of the bones and interosseous membrane ; after which the tibia and fibula are cleared as high as the level of the upper end of the outer incision, the finger-tip being still used in detaching the parts anterior to the interosseous membrane.

In order to avoid splintering the fibula, it is best to saw both bones at the same time, and to finish the fibula before the tibia. The sharp angle of the spine of the tibia being apt to cause ulceration of the skin over it, should be removed ; and the most convenient way of doing this is to commence with sawing obliquely for a short distance from a point about half an inch above the place where the bones are to be divided transversely. Supposing effectual antiseptic treatment employed, the cutaneous margins of the flaps may be stitched very closely, except at the upper end of the outer incision, which is left open for the drain, and serves admirably for the purpose, as it leads directly from the cut surfaces of the bones, and is dependent in position from the circumstance that the limb reposes on its outer side. Accurate stitching is desirable elsewhere, in consequence of the disproportion of the sizes of the two flaps, which, however, is diminished by making a short posterior flap as advised.

In amputating through the calf on the same principle, the operation is similar, except that, for reasons before discussed,[2] the anterior flap need not be longer than two-thirds of the diameter of the limb ; but, to compensate

[1] See *Medical Times and Gazette*, July 6, 1861. [2] See p. 391.

for its diminution, the posterior flap must be made at least half as long as the anterior, by carrying the knife round the back of the limb at an angle of forty-five degrees through the integuments, and dissecting them up to the level of the upper end of the inner part of the incision, before cutting towards the bones, so as to get rid of the heavy and contractile mass of the sural muscles.

The old flap operation is still employed in the calf by many surgeons, being very readily accomplished by drawing the knife in a segment of a circle across the front of the leg from one bone to the other, transfixing behind them, and cutting first downwards and then gradually outwards, next dissecting up the anterior flap of integument, and clearing and dividing the bones at the level of its base. But it is, as we have seen,[1] a most undesirable proceeding, on account of the bulk of the muscular mass from the calf turned up to cover the ends of the bones. Mr. Spence met this objection by shaving off a considerable portion from the face of the posterior flap after forming it. But though this was undoubtedly a great improvement, it could not give to the operation the advantages of the method by longer anterior flap.

When there is not enough sound integument to admit of the latter method, the modified circular operation of Mr. Syme[2] proves highly valuable, enabling us to form out of the smallest amount of materials a short stump, which is preferable to any that can result from operating higher up in the limb, the patient either retaining the use of the joint or resting his weight with great security and comfort upon the bent knee.

The great merits of Mr. Carden's amputation through the condyles of the femur have been already fully discussed.[3] I cannot but agree with him that the patella should always be removed. In cases of injury it may seem a tempting thing to leave it, sawing off its articular surface, that it may unite with the divided end of the femur ; but having tried this plan before Mr. Carden published, I have found that while it *may* result in an admirable stump, it is sometimes attended with serious inconvenience, from the patella being tilted up from its proper position by the action of the quadriceps extensor. Besides this, the presence of the patella interferes with the adequacy of the covering for the end of the femur, and makes it needful to borrow more integument from the front of the leg than is otherwise requisite. And as regards the ultimate result, when the sawn extremity of the femur has been rounded off by ossific deposit, it proves little, if at all, inferior to the patella for bearing the weight of the body. The only objection to Carden's operation, as described by him,[4] is the occasional occurrence of more or less sloughing of the long anterior flap of skin, in spite of faultless operating. It is plain that the risk of sloughing

[1] See p. 385. [2] Ibid. [3] See p. 387. [4] Ibid.

would be diminished if the flap could be made shorter by not carrying the horns of the incision by which it is formed so high up the limb ; and on making experiments on the dead body several years ago, to ascertain to what extent this could be done without disadvantage, I found that it is by no means difficult, when the parts are in their natural condition, to accomplish the operation without making any anterior flap at all, the integuments in front being divided transversely at the level of the lower end of Mr. Carden's flap. I also found it advantageous to form a short posterior skin-flap, both for the sake of coaptation of the cutaneous margins without puckering, and as a useful addition to the covering for the end of the stump.

With this modification, the operation is performed as follows. The surgeon first cuts transversely across the front of the limb from side to side at the level of the anterior tuberosity of the tibia, and joins the horns of this incision posteriorly by carrying the knife at an angle of forty-five degrees to the axis of the leg through the skin and fat. The limb being elevated, he dissects up the posterior skin-flap, and then proceeds to raise the ring of integument as in a circular operation, taking due care to avoid scoring the subcutaneous tissue ; and, dividing the hamstrings as soon as they are exposed, and bending the knee, he finds no difficulty in exposing the upper border of the patella. He then sinks his knife through the insertion of the quadriceps extensor, and having cleared the bone immediately above the articular cartilage and holding the limb horizontal, he applies the saw vertically and at the same time transversely to the axis of the limb (not of the bone), so as to ensure a horizontal surface for the patient to rest on. The popliteal artery and vein are then secured, and any articular or other small branches that may require it.

When the soft parts are thickened and condensed by inflammation, the integuments cannot well be reflected above the patella with such incisions of the skin. But the difficulty may be got over by cutting into the joint as soon as the ligamentum patellae is exposed, and at once removing the leg by dividing the ligaments and hamstrings ; after which the soft parts can be retracted from the femur sufficiently to permit the application of the saw. The arteries having then been secured, the patella is dissected out at leisure.

As thus performed, Carden's operation takes a little more time and pains than when the integument is divided in the form of an anterior flap ; but these are well rewarded by the ample covering for the bone, the small external wound, and the perfect security against sloughing.

Some surgeons speak highly of amputation through the knee, leaving the articular portion of the femur and the patella, a covering being provided by forming a large anterior and short posterior skin-flap from the leg, the result

being that the patient rests his weight upon the broad rounded end of the bone while the patella is drawn up by the quadriceps to occupy the hollow between the condyles in front.[1] There can hardly, I think, be two opinions as to the superiority of Carden's method to this procedure for carious disease of the knee-joint ; and in cases of injury, when the integuments are sound as far as five inches below the patella, which is the length of the long anterior flap according to the method hitherto recommended,[2] a satisfactory though very short stump may be made below the knee. But from my experience with Carden's operation I feel sure that the amputation through the knee may be much improved by dividing the integument in the circular fashion, slightly modified to permit neat adjustment of the cutaneous margins, in which case it would not only be freed from the risk of partial sloughing of the anterior flap which is admitted by its advocates,[3] but, the posterior integument being made to take a larger share in forming the covering, it would not be needful to go so far down the limb in front, and thus the operation would become available for cases of injury reaching too high in the limb to permit amputation below the knee. And in order to ensure complete adequacy of the covering, the saw might be carried through the middle of the articular end of the femur so as to flatten it without interfering with its breadth, and thus in all probability improve rather than impair the fitness of the end of the stump for bearing the weight of the body. On this matter, however, I cannot as yet speak from personal experience.

In amputation of the thigh, if we except cases in which the soft parts are affected at one side only, where a covering may be advantageously provided from the sound side, the flaps should always be antero-posterior, because, the flexor muscles being no longer counteracted by the weight of the limb, the bone tends to become tilted forwards, so that its extremity would be apt to show itself in the anterior angle of lateral flaps.

In the lower half of the thigh, the method by longer anterior flap, on the principles before considered,[4] will be found easy of execution and excellent in results. Two straight incisions are made through the skin and fat along the lateral aspects of the limb, parallel to its anterior surface, and equal in length to two-thirds of its diameter, and their inferior extremities are connected in front by a straight transverse cut, curved upwards near its ends to join the longitudinal ones, so as to shape out a moderately long rectangular flap with rounded angles, if we may so speak. The knife is then passed round the back

[1] See especially a paper on Amputation at the Knee-joint, by Mr. Pollock, *Medico-Chirurgical Transactions*, 1870.

[2] See Mr. Pollock, ibid.

[3] Ibid.

[4] See p. 388.

of the thigh at an angle of forty-five degrees to its axis, marking out a short posterior skin-flap, which is at once dissected up, the limb being well elevated by an assistant. The anterior flap is next raised so as to contain a moderate amount of muscle, and the soft parts being well retracted, the knife is swept circularly through the muscles, so as to expose the bone for the application of the saw about two inches above the angle of union of the flaps.

The incisions should always be made as far down in the limb as the state of the soft parts permits ; and the skin over the patella, if available, will be employed with great advantage as part of the anterior flap.

For restraining haemorrhage the elastic tourniquet must be applied as high as possible in the thigh, and if its constriction is found to interfere with the due retraction of the soft parts, it is best to saw the bone in the first instance where it is easily reached, and, after securing the vessels and removing the tourniquet, expose the bone at the requisite level, and saw off an additional portion, held steady with a pair of strong forceps.

When digital compression is resorted to, the hands should grasp as much of the circumference of the limb as possible, while the thumbs are placed one above the other over the vessel, as it lies on the pelvis, midway between the symphysis pubis and the iliac spine.

Even in the upper part of the thigh, although the object of having a stump capable of bearing weight upon its extremity is no longer to be considered, the operation above described will be found to yield better results than that by transfixion, by avoiding the redundancy of muscle which is the great defect of the latter method. Nor need this plan involve greater loss of blood. For the posterior flap, being only cutaneous, can be raised without material bleeding ; and the anterior flap, after being shaped by carrying the knife through the skin and fat, may be completed by transfixion, while comparatively little retraction of the soft parts is required, in consequence of the short-cut muscles having little tendency to cause protrusion of the bone. Moreover, all bleeding during the performance of the operation may be effectually prevented by the elastic band applied in the manner to be described in connexion with the next amputation.

Amputation at the hip-joint has of late years been divested of much of the danger that formerly attended it ; so that it now ranks among the well-established operations of surgery.

What may be termed the classical method is to form a large anterior flap by transfixion, disarticulate, and cut a short posterior flap, also from within outwards. The thigh being somewhat fixed, to relax the soft parts of the front of the limb, the point of a knife with a blade fully a foot in length is entered midway between the anterior-superior spinous process of the ilium and the

great trochanter, supposing the left side operated on, and passed in front of the bone till it emerges near the tuberosity of the ischium, or in the opposite direction if the right limb be concerned. The knife is then carried longitudinally with a rapid sawing movement, followed by the fingers of one hand of an assistant, which are introduced into the wound so as to compress the femoral artery securely between them and the thumb, previously placed over it in the groin, his other hand being employed to lift up the large anterior flap as soon as it is completed. The limb being now extended and abducted, the surgeon opens the capsule of the joint by cutting firmly upon the head of the bone ; and as this starts from its socket, he divides the round ligament and the posterior part of the capsule ; and lastly, the thigh having been adducted, to draw the trochanter down out of the way of the knife, he completes the severance of the limb by cutting downwards and backwards through the muscular mass at the back of the thigh.

Attention is now at once directed to the bleeding vessels of the posterior flap, fed by the internal iliac, which are covered in the first instance with a folded cloth, or, what is better, by the tips of the fingers of an assistant ; and when they have been tied the femoral trunk and any of its branches which may require it are secured in the anterior flap.

But though I have described this mode of operating, captivating as it is by its brilliant swiftness of performance, I do not desire to recommend it. Many years ago I was much impressed with a circumstance that I witnessed in the practice of one of my colleagues in Glasgow. He amputated below the trochanters by antero-posterior flaps for malignant sarcoma of the lower part of the femur ; but the part of the bone removed being examined after it had been sawn longitudinally while the vessels were being secured, the disease was found to extend up to the part where it had been divided in the amputation. The surgeon therefore seized the remainder of the femur with powerful forceps and dissected it out from its socket. This was done with great facility and with scarcely any loss of blood ; and it occurred to me that, if the same procedure were adopted when it was intended from the first to disarticulate, shock, which is one of the great dangers of amputation at the hip-joint, would surely be greatly diminished ; for we could not suppose that the powerful impression produced upon the nervous system by that operation performed in the usual way could be due either to the removal of the head of the bone or to the mere extent of the cut surface as such. The correctness of this view has been since strikingly demonstrated by the practice of Mr. Furneaux Jordan, of Birmingham, who, in cases suitable for such a procedure, first divides the soft parts circularly low down in the thigh, and then dissects out the bone from among the muscles

and from the acetabulum through a long incision on the outer aspect of the limb, where the soft parts are comparatively thin and the blood-vessels inconsiderable ; a long boneless stump being the result. Now such an operation involves both disarticulation and the formation of an exceedingly extensive wound ; yet Mr. Jordan's anticipations of increased safety of this method as compared with the old one seem to have been fully realized. Ever since the Glasgow experience to which I have referred, I have myself proceeded on the principle which it suggested ; and while it does not seem to me necessary to push it to the extreme degree advocated by Mr. Jordan, I would advise the following as the method to be generally adopted.

Supposing the right limb operated on, the knife is entered at the posterior part of the great trochanter and carried down longitudinally for about eight inches (if the patient be an adult male), and then drawn across the limb in front and behind through skin and fat, in the form of two crescentic incisions which meet at the inner side of the limb at a point an inch or two lower down than the extremity of the outer longitudinal cut. The semilunar flaps mapped out by the crescentic incisions are then dissected up as in a modified circular operation, the integument being raised about two inches higher than their angle of union at the inner side of the thigh ; after which the muscles are divided where they are exposed and the head of the bone dissected out.

Such a mode of operating, besides the diminished danger from shock, has the great advantage of making truly aseptic treatment easy, instead of almost impossible, as it is when the copious sero-sanguineous discharge which takes place from so large a wound is poured out within a very few inches of the anus, which is the case after the ordinary operation, with the dependent angle of the wound close to the tuberosity of the ischium. After the operation which I have advised, the inner end of the wound having been closely stitched and drainage-tubes introduced at its outer part, there is sufficient space for an effectual antiseptic dressing, which will often be a matter of life and death where so large an extent of irritable and absorbent surface is concerned.

The longer time occupied by the operation is of no consequence now that we have the means of dealing efficiently with the once dreaded haemorrhage. For this purpose I advised in former editions of this work the use of the aortic tourniquet. This instrument, however, has two defects. In the first place, when the aorta deviates to any considerable extent from its normal median or nearly median position, the tourniquet is somewhat difficult of adjustment, and instead of retaining its position by the clamping action of the screw which presses down the pad, it tends to slip to one side on the rounded body of the lumbar vertebra, and must be held in place by a very careful and steady assistant.

And, in the second place, an inexperienced or nervous surgeon may be tempted to screw down the rigid instrument with needless violence and damage the intestine by so doing.

Mr. Davy, of the Westminster Hospital, has suggested a very ingenious mode of compressing the common iliac artery by introducing into the rectum one end of a smooth wooden cylinder two feet in length and about an inch in diameter passed in sufficiently far to permit it to be pressed down upon the vessel on the brim of the true pelvis when the other end or handle of the instrument is carried to the thigh of the opposite side, and then raised so that the rod may act as a lever for which the anus serves as a fulcrum.[1] In most cases in which Davy's lever has been employed it has answered to admiration.[2] But it is intelligible that in case of a short mesorectum it might be impossible without undue force to effect compression of the iliac trunk on the right side ; and of course if the coats of the rectum were unsound, the instrument would be wholly inapplicable. Accordingly, I lately heard of a case in which a gentleman specially conversant with the use of the lever failed to bring it into effective action ; and another case has been mentioned to me where death resulted from mischief done by the end of the rod working in the dark.

Hence I believe it to be wiser to adopt here also the principle of Esmarch's elastic compression. It may be applied either to the aorta or to the extreme upper part of the limb. For the aorta a pad of sufficient size, such as a pin-cushion, adjusted over the vessel about the level of the iliac crests, is pressed down by elastic bands, which, however, ought not to encircle the body directly and so cause inconvenient constriction of the waist, but should be connected with the ends of a rigid object placed transversely beneath the back and extending laterally sufficiently far to protect the sides of the body from compression. A narrow piece of board with two lateral notches at each end would answer the purpose quite well for an emergency as a substitute for the curved piece of stout iron with rings or hooks at the ends recommended by Esmarch.

When the elastic band is applied to the *limb* for amputation at the hip-joint, special arrangements must be adopted to keep it well out of the way of the knife, and also to prevent it from slipping down and becoming useless when the support of the head and neck of the bone is withdrawn by disarticulation. The following method will be found to answer perfectly. An elastic band having been provided sufficiently strong to require the full force of the surgeon to stretch it to twice its length,[3] and long enough to encircle the upper part of

[1] See *British Medical Journal*, May 18, 1878.

[2] See Mr. Pearce Gould, *Transactions of Clinical Society of London*, 1879.

[3] About three of the ordinary rods of red caoutchouc, placed side by side and tied together at their ends, will be found to answer the purpose for an adult.

the limb when in the relaxed condition, and with tapes securely connected with its ends, is placed with one end of the elastic part under the sacrum, while the tape of that end is brought round the pelvis between the crest of the ilium and the great trochanter of the side opposite to that to be operated on, and held perfectly firmly in the vertical position by an assistant. The surgeon then, standing on the side for operation, puts the band fully on the stretch in a direction transverse to the body and brings it up into the vertical position immediately below the iliac crest. Holding it in his left hand (if the right limb is concerned), he next passes his right hand round behind the limb, which has been previously placed in the vertical position to expel its blood, and, changing hands, encircles the thigh as near to the perineum as possible, the scrotum being held well to the other side by an assistant. The surgeon's end of the elastic band being now over the groin, he takes the other tape from his assistant and ties the two tapes together in a reef-bow over the sound side. Another point requires attention. Two pieces of bandage, each about two feet in length, are placed longitudinally upon the skin before the elastic band is applied, one of them over the groin, the other well behind the great trochanter; the middle of each piece of bandage being in the situation where the elastic band is to go. And when the elastic band has been applied, the lower end of each of these pieces of bandage is drawn up so as to convert them into two loops by means of which, in the hands of a steady assistant, the elastic tourniquet is kept drawn well up both at Poupart's ligament and behind the trochanter. If this arrangement is well carried out, the whole operation, including disarticulation, may be done uninterruptedly. Nevertheless, I think it prudent to retain the resistance of the head and neck of the femur so long as the tourniquet is in operation, by sawing through the bone below the trochanters, and at once securing all the vessels that show themselves on the cut surfaces. The tourniquet is then removed while an assistant compresses the femoral at the groin: and when any branches still requiring attention have been tied, the remainder of the bone is seized with strong forceps and dissected out. With the incisions which have been recommended this will be found a matter of the utmost facility and attended with little if any haemorrhage.[1]

[1] The article on Amputation was first published in the 1st edit. of Holmes's *System of Surgery*, vol. iii, 1862. It afterwards appeared in the 2nd edit., vol. v, 1871, and in the 3rd edit., vol. iii, 1883. In its later appearances, while retaining its original features, it was altered in various details in accordance with the progress of knowledge.

ON EXCISION OF THE WRIST FOR CARIES

[*Lancet*, 1865, vol. i, pp. 308, 335, 362.]

To save a human hand from amputation, and restore its usefulness, is an object well worthy of any labour involved in it. When caries affects the shoulder or the elbow, the limb is preserved by excision of the diseased joint, and the brilliant success of these operations naturally suggested a similar procedure for the wrist. The first attempt of this kind appears to have been made as early as the close of the last century by the younger Moreau, who, however, gives but few details of his case. In 1839, a German surgeon, named Dietz, is said to have removed all the carpal bones, together with the ends of the radius and ulna, on account of caries.[1] But as such an operation must necessarily have been very painful and protracted, we cannot wonder that it was not repeated till after the introduction of chloroform, when, in 1849, Heyfelder, of Erlangen, excised the wrist-joint for disease, and he has been followed by many surgeons, both British and foreign, who have adopted various methods of effecting their object.

The results of this practice, however, have not proved encouraging. For although several instances of success have been put on record, it is generally admitted that these are quite exceptional,[2] and amputation is now again considered by most surgeons the appropriate treatment for caries of the carpus.

About two years ago a more hopeful view of the subject was suggested to me by a case of injury under my care in the infirmary. The patient was a young man, seventeen years of age, who had fallen about fifty feet down the shaft of a coal-mine, and, besides fracture of the left thigh, had sustained a compound dislocation of the wrist of the same side, the articular ends of the radius and ulna protruding anteriorly for about an inch and a half through a large irregular wound. I sawed off the exposed portions of the bones, and placed the limb on a splint ; and, commencing passive movement of the fingers early, and maintaining it perseveringly, I had the satisfaction of seeing him, at the end of five months, with a hand nearly as supple and strong as the other, the chief difference between them being that the wrist of the injured side was rather more slender than the sound one.

This case appeared to me to throw light upon excision of the wrist for disease. In the first place, it was clear that no operation, intentionally performed,

[1] See O. Heyfelder, *Operationslehre und Statistik der Resectionen*, p. 262.

[2] See Erichsen's *Science and Art of Surgery*, 4th edit., 1864, p. 768. Holmes's *System of Surgery*, vol. iii, 1862, p. 812.

would do such violence to the tendons as must have been inflicted in that accident, both on the flexors through which the ends of the bones were so rudely thrust and on the extensors wrenched out of their sheaths in spite of the secure connexions of the annular ligament. Hence the favourable issue of this case indicated that the tendons might be very freely dealt with in gaining access to the carious bones without inducing stiffness of the fingers, provided the after-treatment were rightly conducted.

And in the second place, the fact that a useful hand had been retained after the loss of so large a portion of the bones, suggested that the same happy result might follow removal of the whole articular apparatus of the wrist ; that is to say, excision of all the carpal bones, together with the ends of the radius and ulna, and the bases of all the five metacarpal bones.

If this were done, recurrence of the disease, the grand cause of disappointment in excision of the wrist, would, as I hoped, be avoided ; and the operation would be placed on a par with excision of the elbow, which, if properly performed, may be relied on with almost absolute security for complete extirpation of the caries. I have long believed that the reason of the remarkable success attained in this respect by excision of the elbow is that the surgeon (when operating in the manner to which I allude) takes away in all cases, however limited the disease may seem, the entire surface covered with cartilage. For it is in the cartilage that caries commonly takes its origin, and even parts of it which may appear sound in a carious joint seem apt to be affected in an insidious, incipient degree, and if left behind may lead to recurrence of the complaint. But, in excising the wrist, all that has hitherto been aimed at has been to take away such portions of the bones as are found to present unhealthy characters, leaving behind more or less of the articular surfaces, which, from the forearm to the metacarpus, may be viewed with reference to caries as forming a single complicated joint, though subdivided in health into three synovial sacs. On the other hand, if the whole of the structures thus liable to morbid action were cleared out, there seemed good reason to hope that success in excision of the wrist for caries might become the rule instead of the exception.

A few months later two cases of caries of the wrist presented themselves for treatment, and, after some experiments upon the dead body, I resolved to test the new principle upon them, and operated upon both on the 16th of April, 1863. Since that time the practice of our large infirmary has afforded me frequent similar opportunities, which have enabled me gradually to improve both the operative procedure and subsequent management, and also to judge fairly of the ultimate results. These having proved fully equal to my theoretical anticipations, I now feel called upon to bring the subject under the notice of

my professional brethren; and first I will give shortly some illustrative cases, reserving meanwhile the details of the treatment.

Case I.—Elizabeth M'K——, a millworker, aged forty, in good general health, was admitted on the 27th of October, 1862, on account of suppuration of the right carpus, resulting from the hand having been violently pinched in a door. Pus was discharged from openings at the back of the wrist, and the carpal bones were felt to grate upon one another on manipulation.

The disease being of traumatic origin, I hoped it might subside if the limb were kept at rest upon a splint, and free exit were provided for the discharge. This treatment was persevered with for upwards of five months, but proved unavailing; and she also continued to suffer considerable pain. Accordingly, on the 16th of April, 1863, I removed the carpus, and at the same time took off so much of the bones of the forearm and of the five metacarpal bones that the interval between them where they were divided measured two inches and a half. The bones of the carpus and the metacarpal bones of all the fingers proved to be extensively eroded by caries.

Seven weeks after the operation the limb was almost healed and promised a most satisfactory result, when, being an ignorant woman, and mistaking our efforts to maintain the flexibility of the fingers for attempts to break them she ran away from the hospital, and did not show herself again for nearly five months, during which time she had kept the fingers extended and motionless upon the splint she took out with her. Consequently they were almost absolutely rigid, and the movements of the thumb were also extremely limited, so that the hand was nearly useless, while, from the position in which it had been habitually held, it had acquired some tendency to droop towards the ulnar side. It was, however, soundly healed; and, through repeated forcible movement under chloroform to break down the adhesions of the tendons, and the use of a leather splint to support the palm and ulnar border of the hand without interfering with the thumb or fingers, it improved remarkably, and when she left the hospital in April 1864 she could use it for wringing a cloth or knitting a stocking. The improvement has since been progressive. In August it was found that without the splint she could readily lift a kettle of water weighing six pounds, implying a most satisfactory command of the muscles over the newly formed articulation. At first I had aimed at anchylosis of the wrist, but was now much better pleased to see that it retained the power of flexion and extension, eversion and inversion, pronation and supination. Even now (March 1865) the limb is still increasing in strength, in proof of which she lately raised with outstretched hand a pail of coals weighing 16½ pounds. She has for the last

six weeks entirely discarded the support, having found the hand exactly as strong without it. The new wrist is now as firmly knit as the sound one, but more slender in consequence of the radius and ulna having been so freely resected.

CASE 2.—Margaret W——, aged fourteen, a sewing-machine worker, was admitted on the 20th of March, 1863, when she stated that a swelling had appeared five months previously on the back of her right hand, which, however, remained free from pain till within about three weeks, when suppuration occurred. An incision was made by her medical attendant, but this failed to relieve her ; and when she came into the infirmary she was still suffering severely, while there was also considerable swelling of the hand.

FIG. 1.

The limb was placed on a splint and poulticed, but additional abscesses formed and opened, and at length the probe distinctly indicated caries of the carpus.

On the 23rd of May I excised the parts represented in Fig. 1. The carpus was chiefly affected by the disease, but the metacarpal bones of all the fingers were implicated, and the radius was anchylosed to the scaphoid and semilunar. Constant attention being subsequently paid to supporting the wrist and bending the fingers, she progressed steadily, though slowly. Thus seven weeks after the operation, the hand no longer drooped when the arm was extended horizontally ; three months and a half later she could take up a roll of bandage between the finger and thumb ; and when three months more had elapsed she knitted part of a stocking without using any splint. About this time, as she had never learned to write, the nurse of the ward taught her the art, which, being a clever girl, she soon learned ; and half a year afterwards I received from her a letter, well written with the affected hand, requesting a certificate of soundness for the satisfaction of her old employer, who was about to re-

engage her. In August 1864 I saw her again. She was then employed at the sewing-machine, earning ten shillings a week, with the expectation of eleven shillings before long, as she was considered one of the best hands at the work. She still wore a leather support for the palm, but without it could lift a heavy weight with the arm horizontal. She stated that there had been no discharge from the hand for the last two months ; and that the only way in which she could convince her friends of the nature of the operation she had undergone was by showing to them her two arms extended side by side, the affected limb measuring two inches less than the other from the elbow to the finger-tips. Lastly, in December 1864, I learned that the hand was still constantly increasing in strength, and that she was on her full wages.

Case 3.—William C——, aged eighteen, a clerk, was admitted on the 14th of January, 1864. Two years previously I amputated the great toe of his right foot on account of strumous disease. The wound was slow in healing, and in walking with a stick he thinks he over-exerted the right wrist, which became swollen and disabled, though for a long time free from pain. The treatment employed failed to arrest the disease, and at length suppuration occurred ; and a probe introduced through one of the openings by which the matter escaped passed down to carious disease in the carpus. The hand had now been useless for a twelvemonth, and I recommended him to submit to incision, for which purpose he came into the infirmary.

On the 16th of January I removed the carpus, together with the articular ends of the adjacent bones. His progress afterwards was satisfactory. Within seven weeks of the operation he could bend the fingers, and raise the metacarpus by muscular action at the same time ; and five weeks later he left the hospital, able to pick up light objects with the unsupported hand, and to execute to some extent all the natural movements of the wrist-joint. In August, after four months more had elapsed, the actions of the wrist were much more free, and the new joint was so secure that without any splint he could support a kettle of water weighing six pounds and a half upon the radial border of the hand with the arm extended horizontally, and easily lifted a chair with the arm vertical. He bent the fingers imperfectly at the knuckles, but moved their other joints and both those of the thumb very freely, and he could hold a pen so as to write with considerable steadiness. In September all discharge finally ceased. The hand has since remained perfectly sound ; and when I saw him in December 1864 there was nothing in its appearance to attract attention. He was engaged in a situation where little writing was required, but the hand was becoming more and more serviceable for that purpose. Its grasp also was con-

siderably stronger, and he used it occasionally to work the bellows of a forge. He still derived benefit from a palmar support with which he had been furnished, but he had gone without it for a week at a time, and promised soon to be entirely independent of it.

Case 4.—Helen M——, aged fourteen, a schoolgirl, admitted on the 19th of February, 1864, attributed the disease, which had appeared seven months before in her left wrist, to a violent squeeze experienced at that time. Three months after the accident it suppurated, and was opened on the dorsal aspect by a medical man ; but its condition became rapidly aggravated, and at length her parents sent her to the infirmary to have the hand amputated. That this was the only feasible treatment was certainly a most natural conclusion from the appearance presented by the affected part. The hand was enormously swollen both on the palmar and dorsal aspects, and drooped helplessly from ligamentous relaxation ; while the fingers were almost fixed in a semiflexed position. There were several sinuses on the back of the hand, and in front of the wrist a deep ragged grey sore as large as a half-crown, and another smaller ulcer on the palm. Her general health at the same time was much reduced.

But most unpromising as the case appeared, I determined to give the hand a chance, and at the same time test fully the capabilities of the new method. On the 5th of March I removed the carious mass, when the metacarpal bone of the middle finger proved to be so extensively affected that it was necessary to drill it with the gouge into a mere tube, which must have reached to near the knuckle, as a portion of the cartilage in connexion with the epiphysis was removed by the instrument.

The result turned out satisfactory, and she left the hospital on the 30th of July, with the sores and sinuses almost healed, and able to move all the fingers freely, and also, at an earlier stage than in any previous case, to raise the knuckles above the level of the forearm by muscular effort. In October she could support a kettle of water on the radial border of the hand, and her general health was completely re-established. In the middle of December she could take up a quart bottle full of water, holding it by the neck between the forefinger and thumb. She was herself disposed to dispense with the palmar support, but was recommended to continue it, so as to favour as much as possible the rapid increase of strength and usefulness. There had been no discharge for the last month, except a little moisture on the removal of a scab ; and the part once so greatly deformed was nearly natural in appearance. When I last saw her (March 1865), she told me she was learning to work at a sewing-machine, and found her hand thoroughly useful for the purpose.

CASE 5.—Thomas M——, aged twenty-one, a miner, was admitted on the 8th of July, 1864. About six months before, when suffering from small-pox, he was seized with inflammation in the right tibia and the left carpus, resulting in necrosis of the former and caries of the latter. When he came into the hospital the back of the wrist was swollen, and presented two sinuses through which a probe could be passed down to the diseased bone. The hand was extremely feeble, and drooped when the arm was extended horizontally. It was very painful, interfering seriously with his night's rest, and his general health was otherwise much deranged, his pulse being 135, and his appetite impaired, while he was constantly bathed in perspiration.

On the 16th of July I extracted some exfoliations from the affected tibia, and also removed from the wrist the parts represented in Fig. 2. A carious

FIG. 2.

cavity occupied the place of the semilunar bone, and the adjacent part of the cuneiform was excavated. The other carpal bones, except the trapezium, were anchylosed into one mass. Two days after these operations his pulse had fallen eleven beats, and after two days more he was recovering his appetite, and had lost his perspirations, while his former anxious expression was exchanged for that of cheerfulness. The improvement in his general health continued, and the hand made most satisfactory progress. Six weeks and six days after the excision it was soundly healed, and the swelling had entirely disappeared. He could move all the joints of all the fingers and both those of the thumb, and performed to some extent all the natural actions of the wrist. A fortnight later he stood the test of lifting a weight of six pounds and a half with the unsupported hand in the horizontal position of the forearm. In November, four months after the operation, the movements had so greatly increased in freedom and firmness, and the hand had so thoroughly natural an appearance, that it was with difficulty some of my medical friends could be persuaded that the

carpus had been removed at all, more especially as a growth of new bone from the radius presented considerable resemblance to the prominence of the os magnum.

On the 13th of February he entirely discarded the leather support, which for some time he had only worn at night as a safeguard, and now (March) his hand has a powerful grasp, and is in all respects nearly, if not quite, as useful as ever.[1]

Case 6.—Mary Ann L——, aged nineteen, a millworker, was admitted on the 22nd of October, 1864. Her case differed from any of the preceding, in being extremely acute. Ten days before her admission, pain came on at night in the right wrist without any assignable cause, and increased from day to day till it became agonizing. When I first saw her the whole hand and the neighbouring part of the forearm were greatly swollen and fiery red, and contained a considerable amount of pus, which I evacuated by very free incisions. This relieved her only temporarily ; and, when she had been in the hospital twelve days, it was obvious that some very decided treatment was called for. During the whole of that time she had taken nothing but water, and had slept very little, so that her flesh and strength were rapidly diminishing ; and, on manipulation of the wrist, it felt like a bag of loose grating bones.

Though I feared that the tendons might have sloughed from vicinity to such intense inflammation, and that the case was likely to do little credit to the operation, I felt it my duty to remove the carpus with the neighbouring articular surfaces, which I did on the 2nd of November. The carpal bones were found almost entirely detached from one another, and all of them, as well as those of the forearm and the metacarpal bones of the fingers, were eroded by ulceration. The tissues beneath the extensor tendons were so disorganized as to break down readily under the finger ; but, happily, the tendons themselves had not suffered seriously, as was proved by the event.

The second night after the operation she slept without an opiate, and on the following day took some beef-tea ; and from this time forward she regained her strength and flesh as quickly as she had previously been losing them. The cavity produced by excision of the bones consolidated with great rapidity. After three weeks she could pick up a roll of bandage with the finger and thumb of the unsupported hand ; and on the 28th of December (eight weeks from the operation) cicatrization was complete. The wrist was then already firmer than in any previous case at that period, so that the base of the hand could not be moved from side to side at all, though she could herself perform flexion and extension, pronation and supination, with increasing freedom. She could also use every joint of the fingers and thumb, which were growing more and more supple as they gradually lost the thickening of tissue which the acute inflammation

[1] For a further notice of this case see p. 199.

had induced. At the present time (March 1865), though she wears a leather support as a measure of precaution, she can write a fair hand without it, and also employs herself frequently with knitting or crochet-work.

In reading the above cases it will have been observed that the later ones show a superiority over the earlier, both in their rate of progress and in their results. This is due principally to successive improvements which experience has suggested in the mode of treatment.

In the earlier cases I made two longitudinal incisions, both on the dorsal aspect of the limb, one at the radial, the other at the ulnar side, sacrificing in the radial incision the extensor of the second joint of the thumb; then divided the extensors of the carpus opposite the wrist-joint; and having detached the tendons sufficiently from the radius and ulna, removed the articular ends of those bones by means of a small saw and cutting-forceps applied transversely. Next, after separating the tendons from the carpus, I sawed or clipped through the metacarpal bones of the fingers, so as to extract their extremities together with the greater part of the carpus in a single piece, dissecting out afterwards any articular portions that remained.

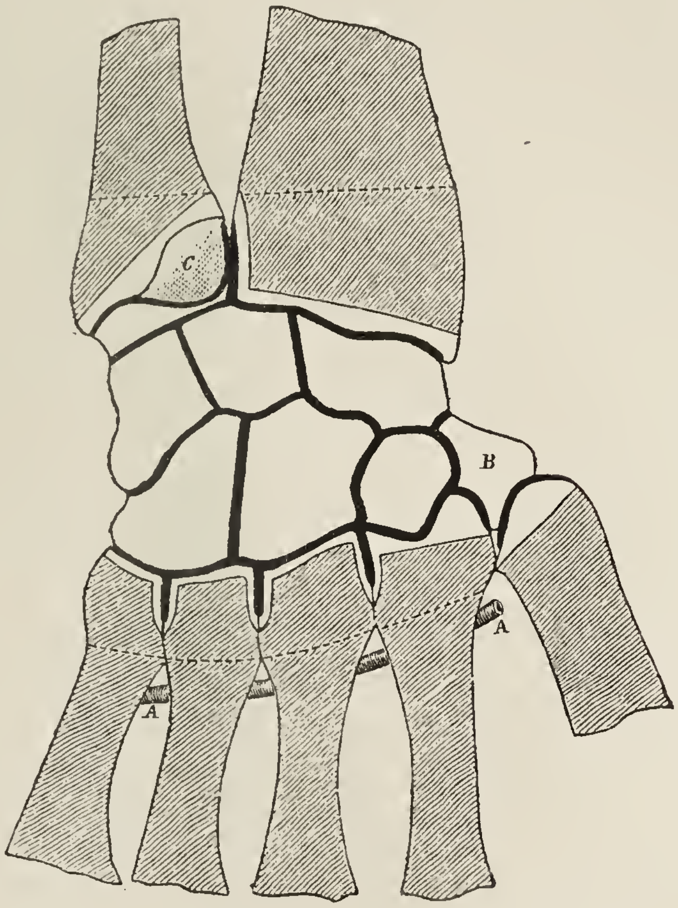

FIG. 3.—*A A*, deep palmar arch; *B*, trapezium; *C*, articular surface of the ulna, over which the radius moves.

This method proved far from perfect, both in the way in which the bones were dealt with and in the mode of gaining access to them.

As regards the bones, it was objectionable in two ways. In the first place, the bones being divided transversely so as to include all the cartilage-covered surfaces, a needlessly large amount was removed both from the radius and ulna and from the metacarpus. In a case of disease apparently limited to the carpus, the essential principle of the operation would be carried out by merely taking away what is represented by the unshaded parts of the accompanying diagram (Fig. 3), taken from a faithful sketch of the bones of the right wrist, the thick lines indicating the extent of the articular surfaces. But the original method sacrificed in all cases at least as much bone as is included between the dotted

lines of the same diagram, and it will be readily understood that the greater loss both of length and breadth of the bones must have interfered seriously with the process of consolidation, and impaired the ultimate strength of the hand. This point may be further illustrated by comparing the sketches in Figs. 1 and 2, of which the former exhibits the parts removed according to the first method in Case 2, and the latter the portions excised on an improved plan in Case 5, which was very similar as regards the extent of the disease.

But a greater objection to the original procedure lay in the fact that, the bones being divided in the dark, there was serious risk of leaving behind some portions of the disease ; for it is, of course, impossible to know beforehand the precise extent of the caries, and when the bones have been confused by operative interference, it is somewhat difficult to judge accurately of their condition.

In order to attain completely the twofold object of taking away all the disease, and leaving behind all bone that may be relied upon as sound, it is desirable that both the radius and ulna and the metacarpal bones should be presented untouched for examination ; and in my later cases this condition has been fulfilled in a thoroughly satisfactory manner by removing the carpus in the first instance, when the free space so afforded permitted me to deal methodically and surely with the other bones.

The soft parts, too, were by no means in the best possible condition after the original operation. In exposing the ends of the bones, and especially the radius, for the application of the saw or pliers, the tendons were separated from their sheaths to an extent which the preliminary removal of the carpus renders quite unnecessary. They consequently acquired a disposition to contract adhesions to neighbouring parts, which occasioned a great deal of needless trouble in the after-treatment.

Again, the division of the extensors of the carpus opposite to the wrist-joint gave less power of raising the hand than was afterwards obtained by cutting them long at their insertions into the metacarpus, and so imitating as nearly as possible the natural arrangement. This point seemed deserving of consideration when the progress of some of the cases had proved that those muscles will regain command over the hand. The idea was first acted on in Case 3, that of William C——, and the result in him and in all that have followed him has shown that it is well worthy of attention.

I also found that by properly planning the radial incision it was quite unnecessary to sacrifice the extensor secundi internodii pollicis, and in the more recent cases the second joint of the thumb has commonly been moved with perfect freedom, whereas in the earlier ones the first joint only was capable of any material motion.

Lastly, it appeared that to have both the incisions on the dorsal aspect of the limb was by no means the best arrangement ; for, while the radial incision must necessarily be at the back of the hand, that on the ulnar side is advantageously made towards the palm, where it gives the most ready access to the palmar surface of the carpus, and avoids injury to the tendons of the extensor carpi ulnaris and the extensor minimi digiti, while it affords a dependent opening for the escape of discharges from the cavity.

The foregoing discussion of the defects of my first mode of operating will, I trust, prevent other surgeons from going over the laborious ground of gradual improvement over which I have travelled, while it will enable the reader to appreciate the advantages of the method which I now venture to recommend.

The operation is performed in the following manner : Chloroform having been administered, a tourniquet is placed upon the limb to prevent oozing of blood, which would interfere with the careful scrutiny to which the bones must be subjected. Before the operation is commenced, any adhesions of the tendons are thoroughly broken down by freely moving all the articulations of the hand. The radial incision is then made in the situation indicated by the thick line (*L L*) in the accompanying diagram of the anatomy of the back of the hand (Fig. 4). This incision is planned so as to avoid the radial artery, and also the tendons of the extensor secundi internodii pollicis and indicator. It commences above at the middle of the dorsal aspect of the radius, on a level with the styloid process, this being as close to the angle where the tendons meet as it is safe to go. Thence it is at first directed towards the inner side of the metacarpo-phalangeal articulation of the thumb running parallel in this course to the extensor secundi internodii ; but on reaching the line of the radial border of the second metacarpal bone it is carried downwards longitudinally for half the length of the bone, the radial artery being thus avoided, as it lies somewhat further to the outer side of the limb. These directions will be found to serve, however much the parts may be obscured by inflammatory thickening. The soft parts at the radial side of the incision are next detached from the bones with the knife guided by the thumb-nail, so as to divide the tendon of the extensor carpi radialis longior at its insertion into the base of the second metacarpal bone, and raise it, along with that of the extensor carpi radialis brevior previously cut across, and the extensor secundi internodii, while the radial artery is thrust somewhat outwards. This prepares the way for the next step, which is the separation of the trapezium from the rest of the carpus, by means of cutting forceps applied in a line with the longitudinal part of the incision—a procedure which, as experience shows, does not endanger the radial artery. The removal of the trapezium is reserved till the rest of the carpus has been taken away,

when it can be dissected out without any considerable difficulty ; whereas its intimate relations with the radial artery and its secure connexions with neighbouring parts would cause a great deal of trouble at an earlier stage of the operation. The soft parts on the ulnar side of the incision are now dissected up from the carpus as far as is convenient, the hand being bent back to relax the extensor tendons of the fingers. The separation of these is, however, best effected from the ulnar incision, which must be made very free. The knife is

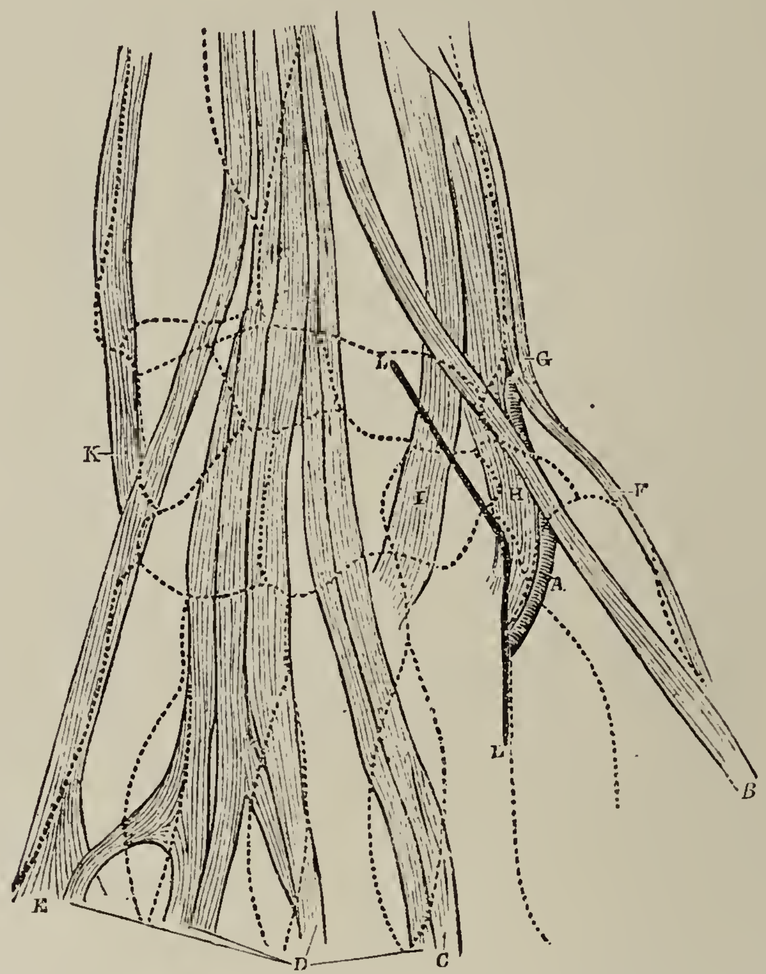

FIG. 4.—*A*, radial artery. *B*, tendon of extensor secundi internodii pollicis. *C*, indicator. *D*, extensor communis digitorum. *E*, extensor minimi digiti. *F*, extensor primi internodii pollicis. *G*, extensor ossis metacarpi pollicis. *H*, extensor carpi radialis longior. *I*, extensor carpi radialis brevior. *K*, extensor carpi ulnaris. *L L*, line of the radial incision.

entered at least two inches above the end of the ulna, immediately anterior to the bone, and is carried downwards between it and the flexor carpi ulnaris, and on in a straight line as far as to the middle of the fifth metacarpal bone at its palmar aspect. The dorsal lip of this incision is then raised, and the tendon of the extensor carpi ulnaris is cut at its insertion into the fifth metacarpal bone, and is dissected up from its groove in the ulna, care being taken to avoid isolating it from the integuments, which would endanger its vitality. The extensors of the fingers are then readily separated from the carpus, and the dorsal and internal lateral ligaments of the wrist-joint are divided ; but

the connexions of the tendons with the radius are purposely left undisturbed. Attention is now directed to the palmar side of the incision. The anterior surface of the ulna is cleared by cutting towards the bone so as to avoid the artery and nerve ; the articulation of the pisiform bone is opened, if that has not been already done in making the incision, and the flexor tendons are separated from the carpus, the hand being depressed to relax them. While this is being done, the knife is arrested by the process of the unciform bone, which is clipped through at its base with pliers. Care is taken to avoid carrying the knife further down the hand than the bases of the metacarpal bones ; for this, besides inflicting unnecessary injury, would involve risk of cutting the deep palmar arch, the position of which is shown in Fig. 3. The anterior ligament of the wrist-joint is also divided, after which the junction between the carpus and metacarpus is severed with cutting-pliers, and the carpus is extracted by seizing it from the ulnar incision with a serviceable pair of sequestrum forceps, and touching with the knife any ligamentous connexions that may remain undivided. The hand being now forcibly everted, the articular ends of the radius and ulna will protrude at the ulnar incision, and are carefully examined and treated according to their condition. If they appear sound or very superficially affected, the articular surfaces only are removed. The ulna is divided obliquely with a small saw, so as to take away the cartilage-covered rounded part over which the radius sweeps, while the base of the styloid process is retained. The ulna is thus left of the same length as the radius, and this greatly promotes the symmetry and steadiness of the hand, the angular interval between the bones being soon filled up by fresh ossific deposit. The end of the radius is then cleared sufficiently to permit a thin slice to be sawn off parallel to the general direction of the inferior articular surface. For this purpose it is scarcely needful to disturb the tendons in their grooves on the back of the bone, the bevelled ungrooved part being enough to remove, and thus the extensor secundi internodii pollicis may never appear at all. This may seem a refinement ; but the freedom with which the thumb and fingers can be extended, even within a day or two of the operation, when this point is attended to, shows that it is important. The articular facet on the ulnar side of the bone is then clipped away with bone forceps applied longitudinally. If, on the other hand, the bones prove to be deeply carious, the pliers or gouge must be used with the greatest freedom ; for it is of course far better to take away too much bone than too little, and my earlier cases, as well as some more recent ones to which I have not yet alluded, prove that a useful hand will result in spite of very extensive excision. The metacarpal bones of the fingers are next dealt with on the same principle, each being in its turn closely investigated, the second and third being most readily

reached from the radial incision, the fourth and fifth from the ulnar side. If they seem sound, the articular surfaces only are clipped off, the little facets by which they articulate with one another being removed by the longitudinal application of the pliers, as is indicated in Fig. 3. On the other hand, we have had in Case 4 an illustration of what may be required when the disease proves extensive ; for it may be remembered that in that case it was necessary not merely to take away the whole base of the metacarpal bone of the middle finger, but to drill its entire shaft into a hollow tube, and yet a sound and most useful hand was retained.

The trapezium is next seized with a strong efficient pair of forceps, and dissected out so as to avoid cutting the tendon of the flexor carpi radialis, which is firmly bound into the groove on its palmar aspect, the knife being also kept close to the bone elsewhere to preserve the radial artery. The thumb being then pushed up longitudinally by an assistant, the articular end of its metacarpal bone is cleared and removed. This may seem a superfluity, as this bone articulates with the trapezium by a separate joint. But besides the possibility of its being affected through its immediate vicinity to the other articulations, the symmetry of the hand is promoted by reducing it to the same level as the other metacarpal bones. Lastly, the articular surface of the pisiform bone is clipped off, the rest of the bone being left, if sound, as it gives insertion to the flexor carpi ulnaris, and affords attachment to the anterior annular ligament, and may serve other useful purposes in the palm. But if there is any suspicion of its unsoundness, it must be dissected out completely. The same applies to the process of the unciform. It may be observed that the extensors of the carpus are the only tendons divided ; for the flexor carpi radialis is connected with the second metacarpal bone below its base, and so escapes. But if it should be cut, there is no doubt that, like the extensors, it would acquire new and secure attachments. The tourniquet being now removed, it will probably be found that either no vessel at all requires ligature, or merely one or two superficial branches. The radial incision is stitched closely throughout, and also the ends of the ulnar incision, as it is desirable that union should take place there, and more especially over the end of the ulna ; but the middle of this incision must be kept open by pieces of lint introduced lightly into the wound to give support to the extensor tendons, and to ensure a wide opening into the cavity, which may serve for the free exit of the pus which must necessarily be formed there. The limb is placed upon a suitable splint, and dressed with some porous material, arranged so as to avoid pressure upon the lines of incision, in order that it may absorb without obstructing the discharge.

To the general reader the above description will, I fear, have proved weari-

some; but to any one about to perform the operation, all the details will, I believe, be found well worthy of attention. The procedure consists, in fact, of a series of operations, each one of which must be executed with scrupulous care. But none of them will present any difficulty to a surgeon who has refreshed his knowledge of the anatomy of the parts, and carefully studied the various successive steps of the process. The operation is, however, necessarily tedious; and no one ought to undertake it who is not prepared to bestow upon it a great deal of patient attention. But, considering the importance of its object, its tediousness must not be regarded as an objection, more especially as the surgeon alone feels the disadvantage. For the tourniquet prevents the loss of a drop of blood beyond what is in the veins of the hand at the outset, and the patient sleeps tranquilly under chloroform; and if this is given by any intelligent assistant in accordance with the safe and simple principles which I first learned in the Edinburgh school—and have since done my best to diffuse,[1] but which, I regret to say, are still too little appreciated by the profession—it is a matter of entire indifference whether its administration is continued half an hour or an hour and a half. Under such circumstances, anything like hurry is as uncalled for as it would be fatal to success.

The after-treatment also requires much care, and has undergone great improvement through experience; and, indeed, the superior results obtained in the more recent cases are due even more to this cause than to the better method of operating.

The principal objects to be kept in view are, to maintain flexibility of the fingers by frequently moving them, and at the same time to procure firmness of the wrist by keeping it securely fixed during the process of consolidation. To the latter indication I paid scrupulous attention from the first; and hence I have in no instance met with any approach to the flail-like condition of the new joint which otherwise would certainly have occurred. Indeed, my anxiety to avoid interference with the process of repair at the wrist led me at first to abstain from moving the knuckles, and to restrict the exercise of the fingers to their middle and distal joints. Consequently, in the earlier cases the movements of the knuckles are still very limited; experience having shown that any one joint which is not freely and frequently moved is apt to become permanently rigid. Another circumstance which interfered at first with my obtaining the best results was a needless dread of suppuration of the opened sheaths of the tendons, which made me afraid to disturb them during the first week. But I was gratified to find, in case after case, that nothing of the sort

[1] For an investigation of these principles see an article on Anaesthetics, by the author, in Holmes's *System of Surgery*, vol. iii, third edition (reprinted at page 135 of vol. i).

ever occurred—a fact which must, I suppose, be attributed to the entire absence of tension in the soft parts, ensured by the free removal of the bones. Thus I have gradually grown more bold, and now do not scruple to ask the patient to demonstrate his command over the joints of the thumb and fingers on the first day, and make a point of commencing passive motion on the second day, whether the inflammation has subsided or not; and from this time forth it is continued daily till it ceases to be necessary. In executing these movements each finger is both flexed and extended to the full degree which is possible in health, care being taken that the metacarpal bone concerned is held quite steady, to avoid disturbing the wrist.

By proceeding in this way, even though the fingers have been previously stiff, it is easy to maintain the suppleness produced by the free movement under chloroform immediately before the operation as recommended above. For an adhesion only one day old yields without much force on the part of the surgeon or much pain to the patient, whereas a very few days will give it such firmness as will require great violence to rupture it.

The splint which I used originally was a flat one, on which the hand lay with the fingers extended. But I have found it a great improvement to have the hollow of the palm supported upon an obtuse-angled piece of thick cork (Fig. 5, *C*) attached to the splint, a convenient cement for the purpose being gutta-percha fused with a hot iron. The hand thus lies semiflexed, which is its natural position of repose; and has also the advantage that the fingers are midway between the extremes of flexion and extension into which it is necessary to bring them in the daily passive movements, while a certain range of voluntary motion is also permitted, which the patient should be encouraged to exercise frequently during the day. At the same time, this position is best adapted for allowing the extensors of the carpus to acquire fresh attachments. Lastly, the palm being applied to the sloping surface of the cork, the splint is kept from slipping upwards; while any movement in the opposite direction is prevented by giving the turns of bandage which encircle the wrist a purchase upon a transverse bar of cork (Fig. 5, *D*) attached to the under surface of the splint about the level of the knuckles. The great essential as regards the wrist—that of perfect steadiness—is thus effectually secured, the hand remaining fixed throughout the day, however freely the fingers be moved. While the patient is confined to bed the limb should rest upon a sloping piece of wood or desk, which is much more steady than a cushion, the inner condyle being well padded with cotton to avoid bed-sore.

The bar of cork beneath the splint has the further advantage of allowing the thumb to fall below the level of the rest of the hand into the position in

which it is most serviceable for opposition to the fingers. For if it be pushed upwards by resting on a board or cushion, it will be apt to retain permanently its unnatural attitude ; its basis of support, removed in the operation, being reproduced in accordance with its altered circumstances. For the same reason, the piece of cork on which the hand rests should be well hollowed to receive the ball of the thumb. The thumb itself is apt to become drawn, in time, towards the index-finger, which would greatly impair its usefulness ; but this is readily avoided by taking the precaution of keeping the thumb, from the first, completely extended by a substantial pad of cotton in the angle between it and the fore-finger, the pad being of course removed once every day for exercise of the joints.

Pronation and supination, also, must not be long neglected ; and as the

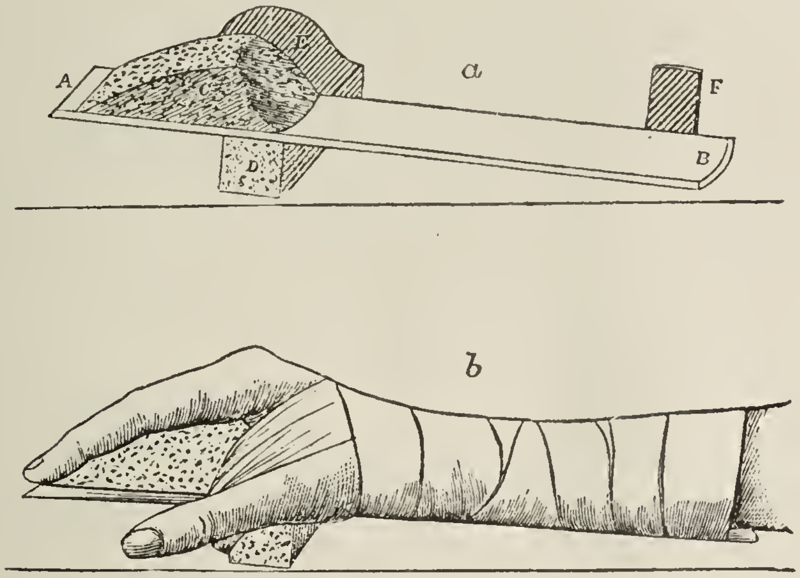

Fig. 5.—*a* represents the splint, of which *A B* is the wooden part ; *C*, the piece of cork to support the hand ; *D*, the transverse bar of cork beneath ; *E*, the ledge of gutta-percha for the ulnar border of the hand to rest on ; *F*, another ledge of gutta-percha. *b* shows the limb bandaged to the splint.

new wrist acquires firmness, flexion and extension, abduction and adduction, should be occasionally encouraged.

As to the length of the period during which passive motion may be required, the rule must be to continue it till the disposition to contract adhesions finally ceases, and this may be after a few weeks or not till months have elapsed.

When the patient leaves his bed and carries his arm in a sling, the weight of the hand will make it gradually droop to the ulnar side, unless it is properly supported. This is conveniently done by affixing two ledges of gutta-percha (Fig. 5, *E* and *F*) to the ulnar side of the splint—one for the border of the hand to rest on, and another, towards the upper part of the forearm, to keep the splint from shifting laterally.

When the hand acquires strength enough to be useful, more free play for the fingers should be allowed by cutting off the part of the splint on which they

rested—viz. all of it beyond the knuckles, leaving only enough to support the hollow of the palm. The thumb must also be left free for use during the day, but at night it should still be kept extended with the pad before mentioned; and if there be any defect in extension of the fingers, they may be kept bound at night to a piece of thick gutta-percha applied to the back of the limb, and bent upwards at an angle at the knuckles. The gentle and continuous traction of the elasticity of the gutta-percha will soon correct the fault.

With regard to the dressing, after the first twenty-four hours I have found a poultice the best application for a few days, and afterwards lint soaked in a solution of some stimulating agent, such as sulphite of potash, which I tried some time ago, on theoretical grounds, for the treatment of sores, and have found preferable to the ordinary astringents, diminishing the amount and fetor of the discharge, and producing a very healthy state of the granulations. It may be used in the proportion of ten grains to an ounce of water.

Even after the hand is healed some support will still be required for a considerable period, and this may be conveniently made of bend leather, accurately moulded to the anterior aspect of the limb, and reaching from about the middle of the forearm to the level of the knuckles, which it rises to support, its ulnar border being turned up for the side of the hand to rest on, while at the radial side it gets a purchase on the base of the metacarpal bone of the thumb. A few turns of bandage, or a laced piece of soft leather, above the wrist, will be sufficient to keep it securely in position, the apparatus scarcely showing at all at the back of the hand.

This support must be worn till the patient feels the wrist exactly as strong without it as with it. It is a most serious mistake to lay it aside too early. Case 1, in which after the lapse of a year and three-quarters the necessary condition for abandoning it was at last fulfilled, is a striking instance of the advantage derived from its persevering employment. Considering the very large amount of bone removed in that case, I confess I hardly hoped for such perfect firmness as was ultimately attained; and I feel sure that if the rule I have given had not been followed, the result would have been very different. The use of the support, far from hampering the motions of the fingers, favours their usefulness. For it seems to be a principle in physiology that the nerves refuse to call the muscles into action unless they can do so with effect; and so, when the wrist has not the firmness mechanically necessary for the efficient action of the fingers, their movements are feebly executed; but when the wrist is firmly supported, the motor apparatus of the hand is, so to speak, encouraged to its best efforts, and recovery of the power of the limb is greatly promoted.

One or more sinuses may remain open for a long time, just as after excision

of the elbow-joint, without anything being wrong with the bones ; as, for example, in the case of Margaret W—— (Case 2), in which they did not finally close for more than a year after the operation. Or, again, the persistence of sinuses may depend upon small exfoliations, and these may prove extremely slow in separating. This may be illustrated by

Case 7, that of James M'G——, sixteen years of age, whose right wrist I excised on the 21st of November, 1863, on account of disease of spontaneous origin, which had attained to much the same exaggerated degree as in Helen M—— (Case 4), and presented similar apparently hopeless appearances: the hand, greatly swollen and discoloured, and with numerous sinuses and a grey palmar sore, hanging helpless at an angle of about sixty degrees, with the fingers stiff and clawed. The radius and ulna were very freely resected, and it was necessary to apply the gouge to the third and fourth metacarpal bones on account of extension of the disease below their bases. All went on well after the operation, except that a sinus remained in each line of incision, and a probe introduced into that on the ulnar side passed down to bare bone of irregular surface. This made me fear a return of the disease ; but, as the wrist was growing firm and the hand useful, I did not interfere, and after the lapse of ten months a small exfoliation escaped from the ulnar aperture. The probe, being then introduced, no longer came in contact with any bone ; and now, three months later, the sinus has become reduced to an almost invisible aperture, which yields only a minute drop of limpid liquid, while the new joint at the wrist is all that can be desired both in firmness and flexibility.

Hence so long as swelling and discharge diminish, and the strength of the hand increases, no interference is called for. But should the opposite conditions present themselves, recurrence of the disease must be suspected, and the part must be submitted to a thorough exploration, which should not be too long delayed, since caries reappearing at a limited spot will spread in time to all the bones.

This course I have found it necessary to adopt in more than one instance, as, for example, in the following case, which was in some respects the worst I have had to deal with.

Case 8.—Mrs. C——, aged twenty-five, a married woman, came to the infirmary for the purpose of having her right hand amputated, on account of spontaneous disease of the carpus of two years' standing, attended for eighteen months with constant discharge, and for the last six months with such severe pain as to deprive her to a great extent of her night's rest, while the effect upon her general health was marked by her wasted and sallow aspect, impaired appetite, and rapid pulse.

Some idea of the appearance of the wrist may be gathered from the accompanying illustration (Fig. 6), taken from a photograph, and also from the fact that the wrist measured nine inches and three-quarters in circumference, whereas the sound one was slender both from natural conformation and from emaciation. The surface of the swollen part was studded wth eight sinuses, through which the probe could be passed down to diseased bone in the forearm, the carpus, and the metacarpus. The hand drooped when the arm was extended, and the fingers were entirely useless. On the 8th of June, 1864, I performed the operation, which proved very laborious on account of the condensation of the soft parts and the extraordinary enlargement of the radius from inflammatory hypertrophy, which made it impossible to protrude it as usual at the ulnar incision for the application of the saw, while its texture was so hard as to require considerable force with the most powerful cutting-pliers to divide it.

Fig. 6.

For seven weeks all went on perfectly well, so that at the end of that time the circumference of the wrist was diminished by an inch, and she could readily pick up a light object with the finger and thumb of the unsupported hand, which drooped but slightly below the horizontal level. She was also quite free from uneasiness, and her general health was greatly improved. Unfortunately, however, the sores, which were previously healing kindly, were now attacked by hospital gangrene ; and though this was checked in about five days by the application of nitric acid and other measures, the previously satisfactory progress was no longer observed ; and, when a month had elapsed without improvement, I resolved to investigate the cause. Having put her under the influence of chloroform, I opened up the line of the ulnar incision, and, finding the end of the ulna again carious, removed it with pliers ; but was pleased to find, on introducing my finger into the cavity that still existed, that the large cut surface of the radius was smoothly covered with granulations, as also were the ends of the metacarpal bones. I therefore brought the edges of the incision together by stitches, except a part sufficient for the escape of discharges, and placed the limb again upon the splint. From that time forth she has advanced satisfactorily ; and when she last came from her native town to see me (December 1864), the discharge had almost entirely ceased, the swelling was greatly reduced, and although the end of the radius was still very large, and the wrist measured eight inches and a quarter in circumference, the border of the bone was to be felt immediately beneath integument of normal thickness and consistence, and

the hand had a thoroughly natural appearance. She could extend it unsupported without any droop, and even raise it above the level of the forearm by muscular effort. She had discarded the sling, and, by help of a light splint, found the hand of much use to her, the movements of the thumb and fingers being very satisfactory.

In this case return of the disease appeared to be produced by an attack of hospital gangrene, and I am inclined to attribute to the same cause a similar occurrence in the following instance.

Case 9.—Alexander C——, aged eighteen, a calenderer, was affected with spontaneous caries of the ulnar side of the right carpus, for which I performed excision of the wrist on the 22nd of July, 1864. Four days afterwards the ulnar incision was affected with hospital gangrene, which was subdued in the course of a few days by local treatment. The hand then progressed very favourably up to a certain point, and in a few weeks he could freely flex and extend all the joints of his fingers, which before the operation he could scarcely move, and had perfect use of his thumb and a strong wrist. The ulnar incision, however, refused to heal completely, and the soft parts in the vicinity continued thickened, and towards the close of the year the swelling there appeared to be on the increase. Suspecting some return of the disease, I opened up the ulnar incision on the 2nd of December, but could not find anything amiss. The wound, however, continued remarkably languid, making in three months scarcely any progress in healing; and at length, on passing the probe down to the pisiform bone, I felt it bare and rough. Accordingly, on the 28th of February, 1865, I put the patient under chloroform, and, after extending the incision sufficiently to gain access to the pisiform, I dissected out the whole of that bone, which was the only diseased part that I could discover. During the month that has since elapsed, the healing, so long delayed, has made good progress, and as there is now no discharge from the deeper parts, I hope to see the hand before long soundly cicatrized.

There is yet a third case with which hospital gangrene appears to have had the same relations.

Case 10.—Jane S——, aged twenty-three, a millworker, with idiopathic caries of the right carpus, had the wrist excised on the 23rd of March, 1864. For two months and a half the appearance and power of the hand promised an excellent result, when it was seized with hospital gangrene, and from that time it gradually deteriorated, till at length, on the 26th of August, I explored it under chloroform, and found very extensive disease in both bones of the forearm and in the metacarpus. I removed with cutting-pliers the affected

parts, so far as I was able to judge of their extent ; but I omitted to examine the metacarpal bone of the thumb, and, whether in consequence of this or not I will not pretend to say, the operation did not prove successful ; and on the 29th of January, 1865, being loth to sacrifice the hand, I re-excised a second time, and found carious disease again present in the ends of all the bones, including the metacarpal bone of the thumb, which this time I made a point of examining, reopening the radial as well as the ulnar incision. The operation, however, was an extremely troublesome one, and far from being as definite and satisfactory as a primary excision ; and even now, although she can move the thumb and fingers, and it is evident that the hand would be a thoroughly useful one if it would heal, I feel by no means satisfied that it will do so.

The lesson to be learned from such a case is the necessity of using all means by which recurrence of the disease may be avoided, and not too long delaying exploration of the wrist when it is suspected.

It remains to say a few words regarding the mode in which the new joint at the wrist is produced. It appears that the bones of the forearm and of the metacarpus become approximated, partly by shortening of the limb and partly by the growth of new osseous material from their divided ends ; and I find that, as a general rule, about half an inch in length of new bone is formed, and that the rest is effected by shortening. The new bone appears to be generally developed in about equal proportions from the radius and ulna and from the metacarpus, but sometimes in an irregular manner. Thus in two instances I have observed a process grown from the ulnar side of the radius, and received between two lateral portions from the metacarpus, so that a secure joint on an entirely new principle was the result.

With proper care on the part of the surgeon, perfect symmetry of the hand can be always ensured ; for the radius and ulna above, and the metacarpus below, being divided in parallel lines, the shrinking of the new material between them draws the hand equably upwards towards the forearm. In this respect the operation above recommended has a great advantage over any partial procedure in case of disease apparently confined to one side of the carpus, independently of the paramount consideration of its greater security of eradicating the caries. And any scruple which I might once have felt in recommending total excision for limited disease has been entirely removed by the usefulness of the hands which have been subjected to it.

It will no doubt appear desirable that I should allude, however briefly, to the rest of the cases that have come under my care. They are five in number, and include some of the best and some of the worst. Among the former is to be mentioned, first, my last case, that of E. P——, aged thirteen, a strumous

girl, whose right wrist was excised on the 27th of November, 1864, for caries limited to the lower and outer part of the carpus and the base of the second metacarpal bone, which appeared to be affected with tubercular deposit. The hand had been useless for a year, but is now already useful as well as sound and of perfect shape, with better movements than in any former case at the same stage.

Next is James B——, aged twelve, with disease of the left wrist, limited to the lower and ulnar side of the carpus and the fifth metacarpal bone, which was enormously thickened and diseased in its interior throughout almost its entire length. Rest and constitutional treatment having been tried in vain for five months, I proceeded to operate on the 14th of August, 1864, and, instead of adopting what would, I believe, be the usual course (amputation of the little finger and its metacarpal bone, with the probability of the disease continuing in the carpus), I excised the wrist, leaving the little finger, though it was necessary to drill its metacarpal bone into a tube with the gouge. He has now a beautiful and most useful hand, which is constantly increasing in strength, though there still remains a sinus over the base of the fifth metacarpal bone, from which a small exfoliation recently escaped.

Third in order must be placed Andrew C——, aged nine, with disease of the left wrist of eight months' standing, and in so severe a form as to call for immediate treatment. The caries extended from the forearm to the metacarpus, and had produced great destruction in the carpus. The operation was performed on the 26th of November, 1864, and the result has been very satisfactory as regards the improvement in the general health, the strength of the wrist, and the mobility of the thumb and fingers. But there have remained hitherto (four months) two small sores unhealed, and these within the last few days have been affected with hospital gangrene. This has, however, been checked by the application of carbolic acid, and I hope has not penetrated to the bones.

Lastly, I have to record two deaths. Neither of these, however, was directly connected with the operation. One of the patients, Alex. S——, a stone-mason, aged forty-six, the first I operated on, was in truth not a fit subject for excision, except as a means of relieving him of the agonizing pain which he endured from disease of the right wrist; for he was affected with advanced phthisis as well as other complaints, and died of these seven weeks after the operation, which, however, had made him free during the interval from his previous suffering.

The other fatal event occurred also in one of my early cases. The patient, Neil C——, aged twenty-one, had the right wrist excised on the 4th of July, 1863, for extensive strumous caries. But in consequence, as I suppose, of

the imperfection of my first mode of operating, the disease recurred, and, after waiting in the vain hope of improvement for about six months, I explored the bones and performed re-excision. A few weeks later—namely, on the 28th of February, 1864, a spot of redness appeared on the forearm, about mid-way between the wrist and elbow, and next day he had a severe rigor. I was at once called to see him, and, finding evidence of inflammation of a superficial vein leading upwards from the red spot to the elbow, I thought there might be a chance of arresting the pyaemia in its outset by amputating the arm, which I did about three inches below the shoulder, within an hour and a quarter of the occurrence of the first rigor. On examining the veins, I found a mixture of pus and blood in the vessels of the forearm, while those of the arm appeared quite sound. Sulphite of potash, in ten-grain doses, was now administered every three hours, with the view of counteracting the poisonous effect of any septic matter already introduced into the circulation, and this was continued till the 5th of March. After this time he improved for several days in general health, while the stump was progressing favourably ; but just as I was congratulating myself on a cure of pyaemia, pulmonary symptoms appeared, and carried him off on the 23rd of March, twenty-three days after the amputation. Whether the affection of the lung was an aggravated condition of the phthisis under which he laboured, or an unusually remote effect of the pyaemia, I unfortunately had not the opportunity of ascertaining by post mortem examination.

In no instance have I been troubled with secondary haemorrhage or any other bad symptom immediately referable to the operation, which appears to be a peculiarly safe one.

A general review of the cases above related may be stated shortly as follows. I have excised the entire articular apparatus of the wrist in fifteen patients. Of these, two have died of causes independent of the operation, and of the remaining thirteen, one is in an unsatisfactory condition, but not hopeless, two afford good hope of a satisfactory termination, which in the remaining ten may be said to have been already arrived at.

On comparing these results with those of previous practice, bearing in mind that the cases include all varieties of carious disease, sometimes in the most aggravated form ever likely to be presented, and also that they have been treated under the disadvantages of hospital atmosphere, so that I have had to contend in no less than six instances with hospital gangrene and in one with pyaemia it will, I trust, appear that the principles which have guided me are sound, and afford the means of removing one of the greatest opprobria of modern surgery.

CLINICAL LECTURE ON A CASE OF EXCISION OF THE KNEE-JOINT, AND HORSEHAIR AS A DRAIN FOR WOUNDS, WITH REMARKS ON THE TEACHING OF CLINICAL SURGERY

Delivered at King's College Hospital, December 10, 1877.

[*Lancet*, 1878, vol. i, p. 5.]

Gentlemen.—I bring this little girl before you to-day because it is important that you should not only see the patients when they first come under our care in the hospital, not merely have the diagnostic features of their diseases pointed out to you, hear the appropriate treatment discussed, and witness any operations that may be performed, but also follow the after-progress of the cases, and further, because by bringing her into the theatre I can show you what I wish you to notice regarding her very much better than by taking you to her bed in the ward.

Let me remind you of the essential features of the case. As she was brought before you ten days ago, the left knee was bent considerably beyond a right angle, the leg being in fact at an angle of about 45° with the thigh, and we were given to understand that this condition of things had existed from the age of three years, when she was affected with a disease of the knee-joint up till the time of her admission to the hospital at the age of ten. The scar of a sinus was present at one side, but it had long since healed. The limb in that position was of course worse than useless. I also pointed out that it was atrophied; or, to speak more correctly, had lagged behind the other in growth; so that the fibula was $1\frac{1}{2}$ inches shorter than the other, and there was a difference of eleven-sixteenths of an inch between the two feet as measured from the point of the calcaneum to the end of the great toe.

I may remark that this atrophy, or lagging behind in development, seems to be interesting as explaining, in part at least, the corresponding fact after excision of the knee. If that operation is performed in early childhood, it is often observed that as the patient grows to adult life the affected limb is more or less considerably smaller than the sound one. This has been supposed to be due to taking away too much of the ends of the bones so as to deprive them of their epiphyses, but a case like the present points to another explanation.

Here no portions of bone at all had been taken away, no active disease had been present for several years, and the only abnormal circumstance was that the limb had been in a condition incapable of being used like the other. In consequence of this want of use, not only had the muscles atrophied, a thing which you would all have anticipated, as the converse of the hypertrophy that occurs in the blacksmith's arm, but all the textures, including the bones, had grown in a less degree than in the healthy limb. Similarly, after excision, although the operation be successful, and perfect anchylosis between the femur and tibia be attained, the limb is not so vigorous as the other, and in proportion to its diminished activity may its growth be interfered with. I lately saw a case in private practice which illustrates this point still more strikingly. The patient was a boy who had experienced fracture of both bones of the leg in the lower third when a child. The fracture had been overlooked, and the bones had united in a faulty position, so that the foot was considerably inverted. The boy therefore could only walk upon the outer edge of his foot, and that with a very limping gait, except by the aid of an apparatus which, though it enabled him to tread fairly on the sole of his foot, was in itself necessarily cumbrous; and the result had been a shortening of the limb, as compared with the other, altogether out of proportion to the effect of the curved position in which the bones had united; and, just as in the case before you, the foot also was smaller than its fellow. There the interference with full development induced by imperfect action of the limb was still more plainly illustrated than in this little girl, because in the former there had been no disease at all from first to last, but merely the crippling influence of an injury.

To return to the case of the little girl. We had to deal with a limb which was not only useless from its bent position, but which had been so retarded in its growth that, even if perfectly extended, it must be shorter than the other. Hence it was a matter of the utmost importance that the means which should be used to produce extension should add as little as possible to the existing deficiency in length. The joint was not anchylosed, but the hamstrings became extremely tight on any attempt at extension. We therefore proposed to divide the hamstrings by subcutaneous tenotomy, but I led you to fear that this step might not be sufficient to enable us to restore the straight position; for I mentioned to you the fact first brought prominently forward by Prof. Volkmann, of Halle,[1] that in cases like this, in which the knee remains for a long time in a bent position, the lower end of the femur, no longer supported as usual by the articular surface of the tibia, may experience disproportionate growth in the downward direction, often to a very considerable extent. Meanwhile the

[1] See a translation of Prof. Volkmann's paper in the *Edinburgh Medical Journal*, vol. xx, p. 794.

lateral ligaments remaining of normal shortness, while the articular portion of the femur is abnormally lengthened, the tibia becomes locked against the femur when extension is attempted, and the application of violence for the purpose could only lead to backward dislocation. Accordingly we found that after free division of all the hamstrings, together with all tight bands of popliteal fascia, the tibia did become locked in the way I had anticipated, when we tried to straighten the limb.

The abnormal length of the end of the femur being presumably the essential obstacle to extension, I proceeded to reduce it, opening into the joint with a semilunar incision anteriorly without dividing the lateral ligaments, and paring away successive portions of the articular part of the femur until, some superfluous fibrous tissue of new formation having been also removed from the surface of the tibia, I was at length able to effect complete extension, but not without a degree of pressure of one osseous surface against the other which I should not have felt justifiable without antiseptic means.

The manner in which drainage was provided is a point worthy of your attention. Next to the importance of the avoidance of putrefaction in wounds is the prevention of tension by providing a free escape for effused blood and serum. This we have hitherto generally done by means of the caoutchouc drainage-tube of Chassaignac. But in the present case such a tube would have been unsuitable, because the natural position for the drain was that it should run between the ends of the bones which, as we have seen, were pressed together so that the calibre of a caoutchouc tube would have been altogether obliterated, and the drain in a most important part of its course rendered useless. Under these circumstances I used a drain of horsehair, because such a drain operates by capillary attraction through the interstices between the hairs, and those interstices cannot be obliterated by pressure, seeing that the hairs are not individually compressible.

The drain was introduced in a manner which you will often find useful. It may frequently happen that the most dependent part of a wound may have no opening in the skin to correspond with it: thus after excision of the mamma it may turn out, when the operation is concluded, that the wound presents a pocket extending considerably further back than the outer angle of your incision. Under such circumstances it is desirable to make an opening for the exit of the drain at the most dependent part. Now, if this were done by a puncture with the knife, some arterial branch of considerable size might be wounded, involving the necessity of freely enlarging the wound to secure the bleeding-point. But if you take a pair of dressing-forceps, and bore steadily from within outwards, the conical extremity of the instrument will slip past any arterial

branch or nervous trunk without injuring it, and when at length it is apparent that there is nothing but skin between the instrument and the surface, the tough integument is divided with a knife over the point of the forceps, and the blades being forcibly expanded so as to enlarge somewhat by laceration the opening which has been made in the muscles, or other deeper textures, the drain is seized between the blades of the forceps, and drawn into place. So in the present case the most eligible position for a dependent opening was at the outer aspect of the limb, where the use of a knife would have involved the risk of injuring the external popliteal nerve, or of dividing some articular arterial branch. Any such difficulty was avoided by employing the dressing-forceps in the manner described.

It is only right that I should mention, when alluding to the horsehair drain, that its use did not originate with myself. We were led to its adoption in the following manner. Mr. Chiene, of Edinburgh, suggested some time ago the employment of catgut as a substitute for the caoutchouc tube. He hoped by this means to provide adequate drainage through capillary attraction, and at the same time, by virtue of the proneness of the catgut to absorption, to do away with the necessity for the withdrawal of the drain from time to time, which there is when the caoutchouc tube is used, whether for the purpose of shortening the tube or substituting a small one for a large. Mr. Chiene's anticipations were to a considerable extent realized. In all cases in which the wound remained aseptic the absorption of the deeper part of the catgut drain, and consequent falling off of the part outside the wound, might be reckoned on as a matter of course ; and in several cases in which the catgut was so used, both by Mr. Chiene and afterwards by myself, the drainage proved adequate and satisfactory. Mr. White, of the Nottingham General Infirmary, afterwards substituted horsehair for catgut ; not because it was supposed to be superior, but because, whereas the prepared catgut is a somewhat expensive article, a horse's tail is a very cheap one. A notice of this use of horsehair was published by Mr. White's house surgeon, Dr. L. W. Marshall, in the *Lancet* of the 2nd of December, 1876 ; and in the following month it was employed by myself in the Edinburgh Royal Infirmary, in a case of chronic bursitis of the sheaths of the flexor tendons at the wrist, in which it seemed likely to be peculiarly serviceable. In this affection the bursa is distended both above the wrist and in the palm, the cavities thus constituted being connected by a constricted passage under the annular ligament ; and it is desirable that both the expanded parts should be opened to give exit to the fibrinous concretions which are generally present (varying in size from that of a millet-seed to that of a small bean), and, further, that drainage should be provided for effused serum, the operation being

performed antiseptically, in order to avoid the very serious inflammatory disturbance and suppuration which are otherwise apt to occur. I had previously used the caoutchouc tube as a drain in such a case, but I found a difficulty from the liability of the tube to be compressed by the tendons. This might, I thought, be overcome by the use of the horsehair drain, which at the same time would, for this particular purpose, be superior to one of catgut, because the catgut would probably be absorbed before the necessity for drainage would be over. Accordingly I cut down above the wrist, making my way between the tendons of the flexor sublimis to the distended sheath of the flexor profundis, and, as soon as this was opened, passed in a large bullet-probe, somewhat curved, slipped it along under the annular ligament, and pressed it forcibly towards the palm, so as to perforate the palmar fascia while avoiding injury to the palmar arch, and, having divided the skin over the point of the probe, dilated the opening in the fascia with dressing-forceps, and then passed into the eye of the probe a substantial drain of horsehair, which had been well purified by steeping in a 1 to 20 solution of carbolic acid, and withdrew the probe, leaving the horsehair drain in its track. The drain answered admirably, and presented the further great advantage that it could be reduced in bulk in accordance with the diminution of the serous discharge, by drawing out as many hairs as might be desired; and in the course of three weeks, the last portions of the drain having been withdrawn, the wound healed without the occurrence of suppuration from first to last.

While the horsehair has the advantage over the catgut that it can be used when necessary over a longer period, it has, in some cases, the converse superiority that it can be not only reduced in bulk, but withdrawn altogether at an earlier period than is required for the absorption of the catgut; for the catgut, in process of organization and absorption, becomes more or less incorporated with surrounding tissues through the medium of the cells of new formation which invade it, and, if an attempt is made to withdraw the drain in whole or in part, there will often occur inconvenient oozing of blood through the rupture of newly formed vessels. And if, on the other hand, the drain is left intact till the parts of the catgut within the wound are entirely absorbed, there remains a small granulating sore at the place of exit of the drain, which may retard for some days the complete healing of the wound. Further, the threads of the catgut, as they undergo organization, are increased in bulk by the formation of the new cells, and their interstices are liable to be more or less choked, so as to interfere with effective drainage. The horsehairs, on the other hand, lie unchanged among the tissues, and their interstices remain to the last as effective as they were at the outset.

The next case in which I used the horsehair drain was one which you your-

selves witnessed—viz. that of transverse fracture of the patella, treated by laying open the joint, drilling the fragments obliquely, and tying them together by means of strong silver wire. Being apprehensive that blood and serum might be effused into the joint to such a degree as to produce inconvenient tension unless a free exit was provided, I resolved to introduce a drain at a dependent part of the articular cavity; but I feared that, if a caoutchouc tube was used, it might be rendered inefficient by being compressed between the condyle of the femur and the neighbouring tissues. I therefore had recourse to the horsehair, introducing into the posterior and outer part of the joint a drain, about a quarter of an inch in thickness, by means of the dressing-forceps employed as before described. It worked to admiration; for though there was, indeed, in the first twenty-four hours, a very copious sanguineo-serous effusion, as shown by the soaking of the antiseptic gauze, yet not the slightest swelling of the joint occurred, and, after nine days, the small remains of the drain, which had been previously reduced at successive periods, were withdrawn, to allow the puncture to close. The drain of horsehair was as pure and white [1] as if it had been merely dipped in water; having been washed quite clean of the blood which first occupied its interstices by the colourless serum which, after the cessation of the original sanguineous effusion, had been the only discharge. I was so much impressed with the satisfactory working of the horsehair drain in that case that we have since employed it in preference to the caoutchouc tube in all our wounds, and have had good reason to be pleased with the change. (If it be necessary to reintroduce a horsehair drain, it is readily done by taking a wisp of hair of half the thickness required, bending it in the middle at a sharp angle over a probe, and tying a piece of carbolized silk round it close to the probe, on withdrawal of which the drain is left with a rounded end which passes readily into the interior of the wound.)

In the case of this little girl the horsehair drain has worked perfectly well in spite of the pressure to which it was subjected. The flow of blood and serum was, in the first twenty-four hours, extremely free, but there was no appearance of the retention of any of it within the wound. On the occasion of the last dressing, two days ago, more than half of the drain was removed. That dressing took place after an interval of three days, and it would be superfluous to change the dressing to-day, were it not that we may, perhaps, be justified, by the further diminution of the discharge, in withdrawing the remainder of the drain entirely so as to permit its track to close.

[1] I used white horsehair in this case simply because I did not happen to have at hand any of the black, which is generally preferable, because the individual hairs are thicker, while the dark colour has the advantage of making them more conspicuous, especially when they are used for sutures.

I will now expose the limb before you. We take care that this is done under a full cloud of spray. We removed at the last dressings both the stitches of relaxation in the shape of thick wire sutures taking a substantial hold, and the stitches of coaptation, of horsehair, including only the margins of the wound. You observe that cicatrization is almost complete, while there is not the appearance of a particle of pus. The skin is still, as it has been all along, free from inflammatory blush or puffiness. The child has suffered no more uneasiness than would have been anticipated had forcible extension been practised in a much less severe case, without the infliction of an external wound, and her constitutional diturbance has been equally trivial. The position of the limb is even better than at the conclusion of the operation, thanks to the effect of the elasticity of a substantial mass of cotton-wool bound down over the knee outside the antiseptic dressing, while we have the satisfaction of reflecting that the bones of the limb have been shortened only by the extent of the abnormal downward growth of the femur; and I think those of you who have had experience in surgery will allow that it would have been unjustifiable to have aimed at such a result without the use of antiseptic measures. If a joint is excised without such means, all prudent surgeons would agree that enough of the bones ought to be removed to ensure absence of tension.

On raising the limb, I find that the gauze dressing presents evidence of discharge, which, though of the nature of colourless serum, is still in sufficient quantity to make it prudent to retain the drain. We may, however, remove half of what yet remains, and you observe that I do this by withdrawing successive hairs without causing the least uneasiness to the child.

Allow me to direct your attention to the splint on which the limb is placed. It is a piece of Gooch's splint, a material introduced into surgery by Mr. Gooch, formerly a surgeon at Norwich, and exceedingly convenient for purposes like the present. It is made slightly longer than the limb, and as broad as the semi-circumference of the thigh, cut obliquely at its upper end to correspond to the line from the perineum to the great trochanter, and at its lower end it is excavated into a horseshoe to receive the point of the heel. Its flexibility in the transverse direction permits it to form a trough which is well padded with a substantial folded sheet made thicker opposite the tendo Achillis, and when it is bandaged to the limb, the horns of the horseshoe, together with the padding, form a satisfactory support to the sides of the ankle. The foot is kept slightly above the level of the groin, and a piece of thin macintosh cloth over the part of the padding towards the nates sheds the discharge and prevents it from soiling the padding, while the exact quantity of effused serum can be correctly estimated. In the course of a short time, when the discharge becomes trifling

or *nil*, a bandage steeped in waterglass (a mixture of the silicates of soda and potash) will be wound round the limb as it lies in the splint, so as to ensure absolute immobility.

Now, gentlemen, these various matters have been much more easily demonstrated to you here than they could have been in the ward. I was much struck with the difference between the theatre and the ward in this respect when showing in the ward to some strangers, after our lecture this day fortnight, the case of large granulating sore which I have brought before you here on several occasions. Our class is not a large one, numbering only fifty, and I suppose not half that number accompanied me to the ward. Yet in order to show the ulcer, it was necessary that those gentlemen should arrange themselves in two rows, so as to form an alley to admit the light from the window, and even then they stood in one another's way, and only those who were very near the bed could see what would have been shown without any difficulty to the whole class at once in this place. In connexion with that case I may make some further remarks regarding the mode of teaching which we employ.

Let me remind you of the various important matters which that ulcer has afforded the opportunity of demonstrating. First, you recollect how putrid the sore was at the outset, and how we succeeded in purifying it once for all by applying to the epidermis soaked with putrid discharge a strong watery solution (1 to 20) of carbolic acid, which has a special power of penetrating the epidermis, and to the granulations a solution of chloride of zinc (40 grains to an ounce), which experience has shown to have an energetic antiseptic effect upon foul granulations. That we did really purify the sore by this application was proved to you by the fact that, being afterwards dressed with lint containing boracic acid, which is the mildest of our antiseptics, with a piece of prepared oiled silk interposed between it and the granulations, to protect them from the antiseptic, mild as it was, and to ensure constant moisture of the surface, yet when dressed after an interval of a week, the oiled silk, instead of being putrid as it would have been in twenty-four hours under a piece of ordinary lint, had no odour except that of oiled silk itself. The pus had remained free from putrefaction for that long period, though not directly acted on by an antiseptic at all.

You have also had demonstrated to you on that sore some very important truths regarding the properties of granulations. You saw me clip away with scissors a portion of the surface without occasioning the slightest pain to the patient, proving that the granulations constituted a protective layer destitute of sensibility.

Again, we made an accurate pattern of the ulcer in gutta-percha tissue,

and on comparing it with the sore a week later we found that the pattern was already considerably larger than the granulating surface together with the cicatrizing margin already forming round it. Thus you had ocular evidence of the truth that granulations have a tendency to shrink, this being one of the means by which sores are diminished in extent in the healing process.

You also observed how, when the ulcer was protected, as far as was in our power, from irritation, by excluding both putrefaction and the direct action of the antiseptic, the formation of the epidermic pellicle at the edge proceeded with a rapidity never seen under water dressing.

Lastly, how instructive was the result obtained by skin-grafting. You saw that whereas before this operation was performed cicatrization took place only at the edge of the sore, a thin superficial layer of integument, involving little more than epidermis, having been removed with a sharp knife from the inner side of the arm, and the shaving having been cut up on the thumb-nail into small bits, which were placed in succession, with the raw surface downwards, on the granulations, the grafts so planted became each one a centre of epidermic growth on the sore. Thus was illustrated the general fact in pathology, that new structures formed in the repair of injuries are composed only of tissues similar to those in the immediate vicinity, and the equally fundamental fact in physiology, that severance of a part from connexion with the body is not followed by immediate loss of its vitality.

You remember also how, having sprinkled the granulating surface with a sufficient number of grafts, we placed upon the sore the remaining portion of the shaving, about as large as a fourpenny-piece, and this, as you afterwards saw, took root and adhered by its entire under-surface, thus teaching us two great truths. First, it showed that the surface of granulations, if thoroughly healthy, may unite not merely with granulations, but with a freshly cut surface, combining, so to speak, union by second intention with union by first intention. And, in the second place, it afforded of itself conclusive evidence of a most important pathological fact not yet universally recognised, that granulations have no inherent tendency to form pus; for, before sufficient time had elapsed to cause the death of the portion of integument as the result of its severance from vascular connexion with the rest of the body, all pus-formation from the granulations on which it was placed must have ceased; and not pus-formation only, but serous oozing also, which would have been equally incompatible with union of the two surfaces. No sooner did this piece of living dressing, perfectly unstimulating, chemically or mechanically, protect the granulations, than pus-formation and exudation of liquor sanguinis were alike suspended.

These, you may say, are very simple matters. Some of them, at least,

you might all have done for yourselves. Any one of you might, as a dresser, clip away a piece of granulations and see that the proceeding was painless, or any of you might equally easily make a pattern of a granulating sore and prove to himself its shrinking tendency. You might perhaps have opportunities for performing skin-grafting ; and might, for aught I know, draw for yourselves the inferences to be deduced from it.

But, on the other hand, you might very likely fail to do some or all of these things even in the entire course of your studentship ; and if you do not learn these matters when students, you may perhaps never learn them at all. Some of you may become in course of time 'pure physicians', and in that case you will have no opportunity of studying the healing of sores ; and yet it is a subject which concerns the physician as well as the surgeon. If the intestines become ulcerated in typhoid fever, the sores must heal by granulation and cicatrization in a manner precisely similar to that which occurs in an ulcer of the leg. But the physician has no opportunity of witnessing this healing process during life ; and when he sees its effects on post mortem examination, they are probably marred by the results of decomposition. And so with a multitude of other things, which it is easy for me to prove to you by demonstration here, but which the physician can only learn by inference. For medical diseases differ from surgical diseases not so much in their nature as in their situation ; and the same great principles of pathology, and to a large extent of practice also, must guide alike the physician and the surgeon.

Now, these great principles may often be illustrated by extremely simple facts, such as those which you have witnessed in that ulcer. But such simple and rudimentary, or, so to speak, homely, truths are not only much more easily demonstrated in the theatre than in the ward, but would very likely never be taught in the ward at all. In ward visits the surgeon passes from bed to bed, and points out the most striking features of interest in the various cases ; but matters of everyday experience, though concerned with the most fundamental principles of our art, are not likely to receive attention except from some one who is appointed to discharge the duty of impressing upon his class by way of demonstration, not only points of unusual interest, but the most commonplace facts, which, though less attractive, are, in truth, more important to the student.

Thus our clinical course resembles in so far a systematic one that it is our duty, as the material at our disposal permits, to illustrate all departments of general surgery *ab initio* every session. And meeting you so frequently as I do —twice a week—with an attendance on your part as regular as is given to a systematic course, I am encouraged to keep my eyes open throughout the session for the materials requisite for such illustrations.

But though sound general principles are the most important things that we can discuss together, they are, of course, far from being all that we consider. Every case of special interest is brought before you, its diagnosis is carefully considered, and the method of treatment to be adopted is discussed in all its details ; and then, if an operation has to be performed, whether, as is often the case, in the course of the lecture, or at some other time, you are prepared to profit by watching its performance, having all the steps of the procedure clearly in your minds beforehand.

I may take this opportunity of expressing my sincere regret that certain expressions which I employed before I left Edinburgh should have seemed capable of interpretation as casting the remotest possible slur on the surgeons of this metropolis. Nothing certainly was further from my intention. I did, indeed, while speaking under circumstances peculiarly difficult and embarrassing, allow an expression to escape my lips which I should not have uttered under any circumstances had I supposed that my remarks were likely to be published ; and I am truly sorry for the needless offence which I have thus given. For the leading surgeons of London no one, I venture to say, entertains higher respects than myself. I referred not to the London teachers, but to the system on which clinical surgical lectures were given in London ; which, so far as my knowledge extended, seemed to me essentially inferior to that in use in Edinburgh ; partly because they were not demonstrative, and partly because, being given at rarer intervals and in conjunction with one or more colleagues, they could not, from the nature of things, approach to the characters of a complete course.

Not that I wish to underrate such clinical lectures in London as I refer to. In proportion to the ability and experience of the lecturer such discourses have their high value. But referring, as they do, to cases which are not present before the student, and which many of the audience may perhaps never have seen at all, they might often, except for the effects of voice and manner, be as well read as attended. Such lectures are in reality far more ambitious and involve greater talent and literary effort than ours, which are comparatively humble performances, standing much in the same relation to a course of systematic surgery as anatomical demonstrations to lectures on anatomy. But, simple as they are, they fill a place in the medical curriculum which, I believe, is second in importance to no other, and which cannot be filled adequately either by clinical lectures otherwise conducted, or by bedside teaching or tutorial instruction.

My own conviction of the importance of the subject is, at least, sufficiently shown by the fact that upon the question whether or not arrangements

could be made to enable me to conduct my course here exactly in the same manner that, following the example of Mr. Syme, I had found so advantageous in Edinburgh, depended my acceptance or otherwise of the highly honourable offer of a clinical chair in King's College.

[In publishing this lecture I wish to add two remarks in order to avoid misunderstanding. First, that I do not omit bedside instruction, and always warn my class that no lectures can possibly take the place of their own individual work at the bedside, since it is essential, in order that the student may become a competent practitioner, that he should handle diseases as well as see them, and not only witness their treatment by others, but be personally concerned in their management by holding dresserships, &c., in our hospitals. Secondly, I desire to add that, since I used the expressions in Edinburgh above referred to, I have been informed that clinical surgical teaching in London has undergone considerable changes since I was a student, both as regards giving it a more demonstrative character, and in greater frequency and regularity of meetings of the classes. The London schools are both numerous and independent, and the changes to which I allude have, I understand, taken place in different degrees in different institutions. Hence, I can quite understand that my general remarks, made, as I would repeat again, without any view to publication, may have done individual injustice, for which no one could be more sorry than myself.]

AN ADDRESS ON THE TREATMENT OF FRACTURE OF THE PATELLA

Delivered at the First Meeting of the Session (1883) of the Medical Society of London.

[*British Medical Journal*, 1883, vol. ii, p. 855.]

Sir Joseph Fayrer, and Gentlemen.—Some time ago, Mr. Holmes remarked to me that it would be well for me to place before the profession statistics of the operations which I had performed for fracture of the patella. And when you, sir, did me the honour to request that I should open this session of the Medical Society with a paper, it occurred to me that I could hardly do better than act on Mr. Holmes's suggestion. But, before entering on the strict subject of the communication which I have the honour to bring before you, it will be advisable to make some prefatory remarks regarding the circumstances that led me to it. In March 1873, my friend Dr. Hector Cameron, of Glasgow, recommended to my care, in the Edinburgh Infirmary, a case of ununited fracture of the olecranon. Dr. Cameron had formerly been my house surgeon in the Glasgow Royal Infirmary, and I had afterwards for several years the great advantage of his assistance in private practice ; and he reminds me that I had often expressed to him the opinion that the use of a metallic suture, antiseptically applied, which we had employed in ununited fracture of the shafts of the long bones, ought, in suitable cases, to be extended to the olecranon and patella. The patient to whom I refer presented himself to Dr. Cameron in the out-patient department of the infirmary ; and, as he had not at that time beds in the institution, and therefore could not operate himself, he sent him to me. He was a man thirty-four years of age, who, five months previously, had received a blow from a policeman's baton on the left elbow. This occasioned great swelling, which seems to have concealed the true nature of the case from the medical man whom he first consulted. On admission, there was a considerable interval between the olecranon and the shaft of the bone ; and, although the limb was muscular, it was comparatively helpless, as he could not extend the forearm at all without the aid of the other hand. On the 28th of the month (March, 1873) I made a longitudinal incision, exposing the site of the fracture, and, at the same time, bringing into view the articular surface of the humerus ; and, having pared away the fibrous material from

the fractured surfaces, I proceeded to drill the fragments, with a view to the application of the suture. The fracture was oblique from before backwards, as indicated by this diagram. I found no difficulty, with the proximal fragment, in making the drill appear upon the fractured surface at a little distance from the cartilage (see *b*, Fig. 1), but with the other fragment the obliquity of the position in which the drill had to be placed was so great that, instead of the end of the drill emerging at the fractured surface, as I had intended, I found it had entered into the substance of the humerus (*d*, Fig. 1). I therefore withdrew the drill, and substituted for it a needle (*c d*), passing the eyed end in first. Then, with a gouge, I excavated an opening (*e*) upon the fractured

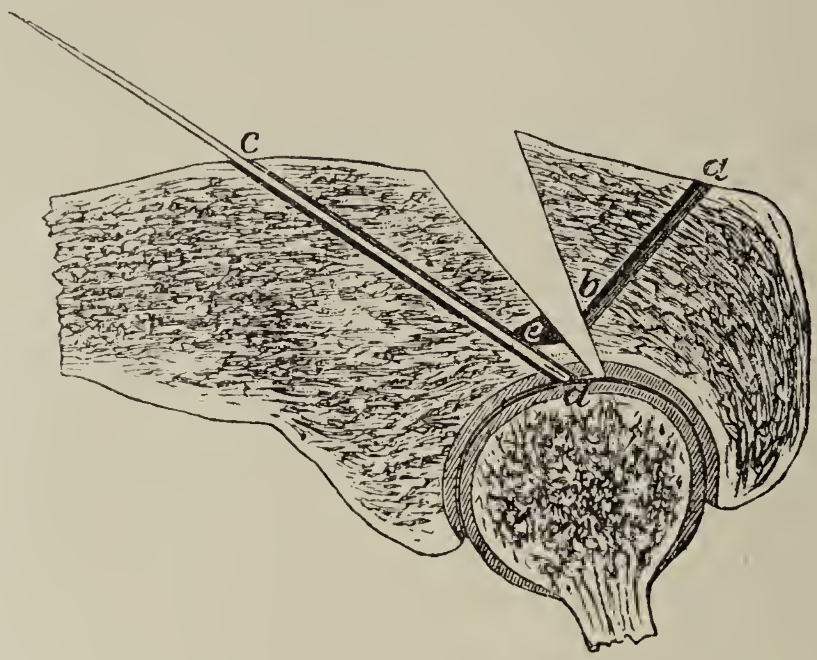

Fig. 1.

surface, opposite to the drill-hole (*b*) on the other surface, until the needle was exposed. Withdrawing the needle, I introduced a silver wire in its place, and I had no difficulty, by means of forceps passed into the excavation made by the gouge, in drawing out the wire. I was then able to pass it on through the other drilled opening, and thus the two fragments were brought into apposition. The ends of the wire were twisted together and left projecting at the wound. Healing took place without suppuration or fever, and the wire was removed on the 19th of May, seven weeks after the operation. The wound made for its extraction soon healed, and the patient returned to Glasgow; and I afterwards had the satisfaction of learning that he was wielding the hammer in an iron shipbuilding yard with his former energy.

I have had two other cases of ununited fracture of the olecranon; and, as these are closely allied to the subject of my paper, I may refer briefly to them. One was a man forty-five years of age, incapacitated for his occupation

as a plasterer by inability to extend the right elbow completely. The ununited fracture of nine weeks' standing was oblique laterally. It was treated as in the last case; the operation presenting no difficulty. It was performed on the 20th of March, 1878. The wound healed without suppuration, but the wire was not completely removed; for, the loop having broken near the twist, the twisted part was alone taken away, and the loop left behind. It never caused any inconvenience, and he afterwards wrote to us from his home at Bristol that he was able to follow his old employment.

The third case was that of a gentleman thirty-three years old, who had consulted no fewer than eighteen surgeons on account of the weakness of his left arm, caused by ununited fracture of the olecranon. I operated on the 28th of July, 1881, paring the broken surfaces as in the other cases, using a chisel and hammer for the purpose; and, having drilled the fragments with a common bradawl, I brought them together with moderately stout silver wire. In this case, however, I did not leave the ends of the wire projecting from the wound; but, having given them one complete twist (or two half twists), cut the ends off short, and hammered the twisted part down flat upon the bone with this small hammer.

The advantage of this practice was strikingly exemplified by the difference in the course of this case from its predecessors. Instead of keeping him under treatment for several weeks until the wire could be removed, I was enabled to allow him to return, fifteen days after the operation, to his home in Wales, with a sound cicatrix; and, trusting to the connecting loop of wire, permitted him to use the elbow freely. I afterwards learned that he was able to drive a four-in-hand as well as ever.

The practice of cutting the ends of the wire short, and hammering down the twist upon the bone, is one to which I shall have to refer again in connexion with my later cases of fracture of the patella. It is in every respect an advantage. The hammering down of the twist renders it more secure than if it is left projecting, to be moved by every shifting of the dressing, and perhaps broken, as in the second of the cases just referred to. We also get rid of a source of disturbance, and sometimes of considerable uneasiness, in the wound. The time of healing is greatly shortened, and the knowledge that the loop of wire securely holds the fragments in position allows the use of the joint to be commenced much earlier than when we have only the organic bond of union to trust to. The practice is also of the highest value in ununited fracture of the shafts of the long bones. The thickness of the wire must be proportioned to the force to which it is to be subjected. For the olecranon, that which I have here is amply sufficient, only about one twenty-fifth of an

inch in diameter. For the shaft of a femur of an adult male, a piece like this, about one-tenth of an inch in thickness, which I have had specially prepared with a view to a case of ununited fracture of the femur which we expect to operate upon in the hospital this week, is requisite, in order to resist with certainty the enormous force of the great muscles of the thigh. The pieces of bone which I hold in my hand were removed, in August 1881, from a case of badly united fracture of the femur. The patient was a gentleman from Rio de Janeiro. The fracture had occurred about the junction between the middle and upper thirds of the bone ; and it had been so badly united that the fragments overlapped very much, and also were at a considerable angle with each other, so that the limb was extremely distorted, as well as much shortened. Bloodlessness of the operation having been provided for by elevation of the limb and the application of an elastic tourniquet, I cut down from the outer aspect of the thigh upon the seat of fracture. Then, with a periosteum-detacher, I separated the soft parts from the place of junction of the fragments ; and, in the next place, I went through the extremely laborious process of cutting through the osseous union (which was of almost ivory hardness) parallel to the axes of the two overlapping fragments. This having been at length accomplished, and the soft parts still further detached, I found that I was able not only to get the limb into a straight position, but also, by very moderate extension, so to reduce the riding of the fragments that, by sawing off comparatively small portions, I was able to bring their extremities into apposition and apply my suture. This was done with wire of about this same thickness. The limb was put up at first with a long splint. I need not enter into details regarding the after-treatment ; but I may say this, that he was a weakly man, and it was some months before absolutely firm union was obtained. It would have been extremely embarrassing to have had the ends of the wire sticking out from the wound all that time. On the contrary, it was a very great comfort to have no occasion to think about the wire ; and ultimately he left for South America, with a perfectly straight limb, almost of the same length as the other, and, at the same time, with thoroughly firm union.

But to return to the immediate subject of my communication. Ever after my first case of ununited fracture of the olecranon, I was on the look out for a fracture of the patella to treat on the same principle. Dr. Cameron, however, anticipated me. In October 1876, being now full surgeon in the Glasgow Infirmary, he admitted a man with transverse fracture of the patella. He treated him, in the first instance, in the ordinary way, and dismissed him at the end of eight weeks with a pretty short and strong ligamentous union. Eleven days later, however, he reappeared, having ruptured the fibrous band

by a violent movement during a state of intoxication. The fragments were then found widely separated. Dr. Cameron again treated him on ordinary principles for eight weeks, at the end of which time the fragments were still so widely apart, and the limb so feeble, that Dr. Cameron determined to cut down and apply the wire suture antiseptically. This he did on the 5th of March, 1877. On making a longitudinal incision, he exposed a condition of the parts, of which, through his kindness, I am able to show you a sketch, viz. a ligamentous union one inch in length, connecting pretty equal-sized fragments, with nipple-like projections extending from their attenuated margins much thinned by absorption. He cut away the fibrous material, and, having pared the edges of the fragments, and drilled them in two situations with a bradawl, he connected them with two sutures of stout silver wire (as shown here in another drawing), the ends of the wires being left projecting at the wound. At the same time, he introduced an independent drain into the joint. The wound healed without suppuration or fever; and, though osseous union was not obtained—which, as Dr. Cameron remarks in his report of the case, was not to be wondered at, considering the thinned state of the surfaces—yet he had the satisfaction of discharging the patient with close approximation of the fragments, and a thoroughly useful limb.

In October of the same year, 1877, a patient with transverse fracture of the patella was admitted under my care in King's College Hospital. He was a man forty years of age, who, while riding on horseback, had his horse stumble and fall. He was thrown over the horse's head, falling on the right knee. He could not rise, and was brought to the hospital. In the first instance, I attempted with this patient to bring the upper fragment down, so that it should be in contact with the lower. For this purpose I applied an apparatus, into the details of which I need not enter further than to say that it was so arranged that the upper fragment, by means of weights and pulleys, was drawn down. Four days later, however, I found that there was still a quarter of an inch interval between the fragments, and I suggested to the patient the operation of cutting down and applying the wire suture. This, however, he would not then consent to, and preferred returning home to be under the care of his ordinary medical attendant. Eight days later, or fourteen days after the accident, he was readmitted, expressing a wish to be operated upon. On the 26th of October, I accordingly proceeded to operate, making a vertical incision, about two inches in length, over the patella, exposing the fragments, which were then one inch apart. My inability to bring down the upper fragment into contact with the lower became explained when the parts were exposed; for there were found between the fragments extremely firm coagula,

with fibrous tissue, fascial and periosteal, mingled with them, constituting so firm a mass as to make it quite impossible for the two fragments to be brought into contact. The clots having been completely cleared away from between the fragments and from the interior of the joint, I applied a common bradawl in the middle line of the patella, drilling each fragment obliquely so as to bring out the drill upon the broken surface a little distance from the cartilage. Pretty stout silver wire was then passed through the drilled openings, and the fragments thus strung upon it were pushed firmly home, and so brought accurately into apposition. Before they were brought together, however, an arrangement was made for the drainage of the joint. This was done on the same principle in all the cases that I have to record, and I may therefore describe the matter once for all. A pair of dressing-forceps, with the blades closed, were introduced from the wound made into the anterior part of the joint to the most dependent part of the outer aspect of the articulation. The instrument was then forcibly thrust through the synovial membrane, the fibrous capsule, and the fascia, until the point of the forceps was felt under the skin. An incision was then made with a knife through the skin upon the end of the dressing-forceps, so as to allow it to protrude. The blades of the forceps were then expanded so as to enlarge the opening which they had made in the deeper structures without risk of causing haemorrhage. The drain was then seized in the forceps that protruded through the wound, and drawn into the joint. The ends of the wire were now twisted together, and the twisted ends brought out at the wound, which was closed with sutures and a small drain inserted. I need hardly say that in this case, as in Dr. Cameron's, antiseptic treatment was employed throughout. It is unnecessary for me to enter into details as to the progress of this case. We have here the temperature-chart for as long as it was thought worth while to have it recorded, and you will see that it indicates, after a little temporary disturbance immediately after the operation, an entirely afebrile condition. The wounds healed without any suppuration. At the end of eight weeks, the wire was removed by an incision through the cicatrix. Eight days later, the wound made for the removal of the wire had healed. At the end of ten weeks from the operation, the patient was allowed to get up, and, though no passive motion had been employed, he could move the limb freely through an angle of about thirty degrees. Two days later he was discharged, and, unfortunately, nothing has been heard of him since. I saw him once in a cart a few days after he was dismissed, but I have not been able to learn any further tidings of him. This, I believe, is the first instance of a recent case of fracture of the patella being treated by wire-suture antiseptically applied.

My next case occurred two years later. William T——, a coal-porter, thirty-seven years of age, was admitted on the 13th of December, 1879. He was a muscular man. The patient slipped on the 9th of December, while carrying a sack of coals, and felt something give way in one knee. On endeavouring to rise, he found himself unable to do so. On admission into the hospital, the right patella was found fractured transversely, the interval between the fragments being about an inch. There was a considerable amount of effusion into the joint. On the 15th of December, that is to say six days after the accident, I proceeded to operate, making a longitudinal incision, as in the last case, about two inches long, over the patella. The lips of the wound being held apart with blunt hooks, a hole was drilled in each fragment in the median line. Stout silver wire was passed, and secured by half-turns. A drainage-tube was introduced, as in the last case. And here, again, there is no need for my entering in detail into the reports. We have before us the temperature-chart. For the first fortnight after the operation, there was what we may call an absolutely afebrile state. During the rest of the time of his residence in the hospital, there were two accidental elevations to 100·5°, but nothing to indicate anything serious. The wound healed, as in the last case, without any suppuration. Six weeks after the operation he was allowed to get up. Eight weeks after the operation an incision was made through the cicatrix for the removal of the wire, the loop of which was cut, and the wire withdrawn. On the 23rd of February, that is a fortnight later, the bandages which had been previously applied to the leg were removed, and it was found that he could bend the limb to a right angle; he could walk well, and was able to kick. On the 22nd of February, 1883, this patient showed himself. We then took the following notes: 'The patella seems perfectly natural, except a trifling irregularity of outline on one side. It is evidently osseously united. The movements of the joint are perfect, from complete flexion to extension. He can kick vigorously. He says the joint is just as trustworthy as ever. He frequently carries a weight of 220 lb. for upwards of 100 yards, and he walks without the slightest limp.'

[The patient was now introduced and exhibited to the Society. He said his limb was as good as ever, and that it never failed him.]

I have not seen the man since the time I have referred to. Except for the linear cicatrix, no one would be able to tell that this patient had had anything wrong with his knee at all.

The next case was one of ununited fracture. The patient, Joseph R——, aged twenty-two, was admitted into the hospital on the 27th of September, 1880. He is a soldier, and stated that, on the 3rd of June of that year, while

running across a green, he slipped upon a piece of turf, and, in trying to recover his balance, he snapped his knee-pan and fell. He was taken to a military hospital ; and the limb was put in splints, which were kept on for seven weeks, a starched bandage being applied after their removal. On admission, the fragments were found separated by an interval of three-quarters of an inch. There was a firm fibrous band of union between them. The knee, however, was quite stiff in consequence, apparently, of the rigidity of the extremely atrophied quadriceps extensor. He was quite unable to walk. If he attempted to do so, he held the leg in his hand. He complained of frequent uneasy sensations in the knee. On the 22nd of October, I cut down over the patella, as in the former case, making an incision about two inches in length. Having cut away the fibrous tissue between the fragments, I refreshed the osseous surfaces, and then, having provided for drainage as before, drilled the fragments, and drew them together with stout silver wire. Nothing occurred worthy of notice until four weeks after the operation, when I proceeded to attempt passive motion. Without chloroform, this proved impossible ; but, under chloroform, I used considerable force, when, the rigid quadriceps extensor refusing to yield, the twist of the wire gave way ; the cicatrix, which had quite healed except where the wire projected, opened ; and there was heard a sound of air being sucked into the joint, the fragments becoming, at the same time, widely separated. I injected the joint with an antiseptic solution, a procedure which I candidly confess I should now regard as probably superfluous. However, such was done ; and, six days later, when all disturbance caused by this second injury and the irritation of the antiseptic injection had passed off, I proceeded to operate upon him a second time. Chloroform was again administered, and an incision similar to the former one was made, the cicatrix being laid open. I then found that the ends of the wire were lying in place, ready to be twisted together. I found, at the same time, a considerable mass of coagula present. These I cleared away from between the fragments and from the joint, twisted the wire again, and thus we had a second operation in one patient. The after-progress was as in the other cases. Here we have a doubly long temperature-chart, because we have two cases in one, so to speak ; but there was no deviation whatever from the normal state ; neither as the result of one operation nor the other has any febrile condition as regards temperature been produced. In due time the wire was removed, and, the wound made through the cicatrix having healed, he was discharged eight weeks after the second operation. He was then able to walk, but with a stiff knee, with scarcely any mobility. I did not attempt any more passive motion after previous experience, and while I was well pleased to see

that he could walk with a stiff knee, whereas he could not walk at all on admission, I hardly ventured to hope for anything better. However, on the 22nd of February, 1883, he presented himself, when the following report was made: 'The patella is perfectly natural, except a little irregularity of the two borders opposite the seat of the fracture. The surface is quite smooth. There is no interval between the fragments. There is evident osseous union. The degree of flexion is increasing. He can bend to an angle of 60°, and extend again completely. He laid aside his stick last summer, and returned to his work as a gardener seven months ago. He can do anything except kneel. In getting over a paling, he has to throw the leg over in a partially extended position. He walks with a barely perceptible limp.' We may now say that he walks with no limp at all.

[The patient was introduced and exhibited. He could now bend his knee nearly to a right angle, and said that he was on his legs all day, and was quite equal to his work as a gardener.]

The great interest in this case seems to me to lie in the improvement that has occurred without any passive motion on the part of the surgeon, and as a mere result of the natural actions of the limb; from such a very rigid state of things as there was when he left the hospital to the condition of mobility which we now witness.

The next case was also one of ununited fracture. The patient, Martha F——, aged forty-three, was admitted on the 5th of November, 1880, on account of an accident which had happened eight weeks before, when she felt something snap in her knee, while trying to save herself from falling. She was unable to walk or move the joint, which quickly swelled up to a large size. No splints had been used, and no treatment of any kind employed. On admission, there was fullness over the knee, and a transverse fracture of the patella to be discovered in the middle of the bone. The fragments were separated one inch. There was fluid in the joint, as indicated by fluctuation. On the 12th of November, I operated as in the last case, paring away the fibrous material between the fragments, and refreshing the osseous surfaces with cutting pliers. The fragments were then drilled obliquely in the middle line, and brought into apposition by means of a suture of stout silver wire. This, however, could only be done when the limb was raised high into the air so as to relax the quadriceps, she being a stout woman, with powerful muscles. Of course, antiseptic dressing was employed; and, as was done in all these cases, the limb was placed in a trough of Gooch's splint, with the upper end oblique, corresponding to the line from the tuberosity of the ischium to the great trochanter, and the lower end excavated in the form of a horseshoe, while the horns of the horseshoe

were well padded, to support the sides of the foot. With regard to this patient, again, I have to show a temperature-chart free from any febrile indication. In eight weeks after the operation the patient was allowed to get up, and she walked about on crutches. She was discharged three weeks later, able to bend the knee slightly, lowering and raising the foot three or four inches.

On the 14th of February the patient was readmitted, to have the wire extracted; and, five days later, she was finally discharged. It will be remembered that this was a case of ununited fracture; and that, when the patient left the hospital, she could only move the foot through a distance of about four inches. On the 22nd of February of this year we had an opportunity of seeing her, and then the following note was taken: 'There is perfect union of the fragments. She can walk from Drury Lane to Billingsgate and back, and walks without a limp. She can bend the knee to a right angle, and says the mobility increases every day. From the position at a right angle, she can raise the leg in a perfectly natural manner to the extended position. She is a stout, heavy woman. She cannot kneel.'

[The patient was now introduced and exhibited. There seems to be a perfect patella; there is nothing abnormal to be felt about it. She says she can do everything except kneeling.]

The next case was one of recent fracture. William G——, sixty-two years of age admitted on the 21st of June, 1881, a healthy man, but a pretty hard drinker. On the morning of his admission he slipped, put out his right leg to save himself, fell, and could not rise. His leg doubled under him. On admission the patella was found fractured transversely, with one inch of interval between the fragments, which could be brought together with difficulty. The knee was considerably swollen. On the 24th, that is three days after the accident, I operated upon him. The operation was conducted precisely as in the cases that have been before described, except that, unlike the two last, there was no necessity for refreshing the fragments. It was merely necessary to take away the clots of blood and any effused fluid from the interior of the joint. A few hours after the operation this patient became delirious, and we were apprehensive of delirium tremens. However, he was quieted with a dose of opium, and gave no further trouble. The temperature-chart here, as in the last case, exhibits entire absence of febrile indication. In this patient, for the first time, the ends of the wire were cut short, and the twist hammered down. The wounds healed without suppuration. Exactly six weeks after the operation he was allowed to get up, and I had the satisfaction of exhibiting him before some of the members of the International Medical Congress, and

showed them that he could raise his limb, from a position of flexion almost at a right angle, to the completely extended posture. I have not seen him from that time until to-day. Having learned that he was employed in a Birmingham establishment, I wrote to my friend Mr. Chavasse, of that city, who replied as follows : 'I saw G. this morning, and have made arrangements for him to leave by the 2 o'clock train to-morrow afternoon. He will be at your house just before 8 o'clock. In case he should not keep his appointment, there is a faint linear cicatrix present over the joint. The knee can be flexed as well as the other. There is bony union of the patella, a faint ridge being felt on the point of union. No suture is to be detected by the touch. At his work, as a stamper, all day long, he works a pulley with the affected limb, which raises a weight of 60 lb. In damp weather he feels very slight inconvenience in the site of the old fracture.' Happily our patient has kept his appointment, so that we are able to see him to-day.

[The patient was introduced and shown. He said he could do anything with the limb the same as with the other. He worked a stamp-hammer, and he could work that hammer, weighing one hundredweight, all day long. There was no difference whatever between the movements of the two knees.]

There is a barely perceptible cicatrix, and he has a perfect patella.

My sixth patient was a woman, Elizabeth C——, fifty-seven years of age. She also was a recent case, admitted on the 21st of October, 1881. Going downstairs, she fell with her left leg bent under her, striking the knee against the ground. She was brought at once to the hospital. The left knee was very much swollen from effusion, hot, and tender ; the fragments of the patella were felt, separated from each other about one inch. I believe it is generally wise to let any distinct inflammatory appearances that exist, as the immediate result of the accident, pass off before the operation. In the former case there were no such, or scarcely any ; therefore we operated three days after the accident. In this case they were manifest, and we allowed a week to pass. The operation was performed just as in the last case. The ends of the wire were twisted with two half-turns, that is to say, one complete turn. The ends were cut short, and then, with the small hammer, the twist was hammered flat down upon the patella.

Here we have the temperature-chart. As we very commonly find, in cases antiseptically operated upon, the first effect of the operation is a depression of temperature. On the evening of the first day there was a depression ; on the following day, a little rise, but that rise only reached 101° ; after that, there was nothing to indicate anything febrile. Two weeks after the operation passive motion was commenced. The wounds were then so very nearly healed

that the milder antiseptic boracic lint was used for the superficial sore which remained. Three weeks after the operation the limb was bent to a right angle; it was painful to her, but caused no disturbance of the fragments. Four weeks after operation, passive motion was again employed; the wounds were completely healed. Six weeks after the operation the patient was allowed to get up, and could already walk fairly. Three days later she was discharged; she could then walk very well. On the 23rd of February of this year we took this note regarding her: 'The patella appears perfectly natural, with the exception that the wire is felt, causing the slightest projection under the skin, which, however, moves freely over it. The movements of the joint are perfect; from complete flexion at a very acute angle to perfect extension. She kneels as she used to do, and only occasionally the wire comes into contact with anything, and then she feels the skin over it tender. She can walk any distance, as before the accident, and does so without a limp.'

[The patient was now introduced to the Society, and confirmed in every respect the previous report.]

My last case is a man sixty-seven years of age, John P——, admitted into King's College Hospital on the 6th of January of the present year. He had fallen from an omnibus on the previous day, striking his knee upon the ground. There was transverse fracture of the patella, and great swelling of the joint. Six days after the accident I proceeded to operate. On making a vertical incision and exposing the seat of fracture, I found a condition of things which, possibly, had I known it, might have induced me to abstain from operating. I found that the lower fragment was very small, and was comminuted. There was one entirely loose piece, as big as a filbert, and another about half that size, which, of course, had to be extracted. Such a condition, taken in connexion with the advanced age of the patient, did not promise well for satisfactory union. Having sponged the clots out from between the fragments and from the joint, and established a drain, I drilled; but as the lower fragment was so exceedingly small, I was obliged to drill, not through it, but through the ligamentum patellae; and, by this means, I was able to bring the large upper fragment into contact with the raw surface below. Now, however, I do not regret having operated upon this poor man. You will see that his temperature-chart is free from any febrile indication; and the wounds healed without any suppuration. Here, as in the last two cases, the ends of the wire were cut short, and the twist hammered down upon the patella. Three weeks and four days after the operation, the wound was nearly healed. The knee was bent through an angle of thirty degrees, and from that position the patient could himself raise it to complete extension; a thing which, with-

out the wire, and without our feeling that the wire was in a very secure form, we should not have thought of permitting. Four weeks after the operation, the wound was healed. The knee was then bent to an angle of forty degrees. Eight weeks after the operation, the patient was discharged, having been for a considerable time before (I have not got it exactly recorded when) allowed to walk about the ward, and walking well. You will observe, gentlemen, that this is my most recent case. He has not had the same time for improvement that the others have had.

[The patient was now introduced, walking up the room without the slightest limp. He said he was getting on 'first-rate'. He found the leg continue to get stronger, and he was able to move it better. He noticed that it was getting stronger every week; he might say every day.]

I confess I am surprised to see how complete a patella this man has, considering how extremely small the lower fragment was. There must have been considerable new osseous formation from the periosteum, because here we feel the central part of the wire, and yet between that and the lower border there is what appears to be a substantial lower fragment connected with the upper one by osseous union. Now we may say he has a perfect patella.

These, gentlemen, are all the cases of fracture of the patella on which I have operated, and I consider it fortunate that I am able to bring before you six out of the seven.

I should like now to say a few words as to the method of operating. The wire employed should be, as I have said, pretty stout, about one-sixteenth of an inch in diameter. I have not found it needful to use more than a single suture of such wire. It is applied in the vertical plane, in the course of the longitudinal incision over the middle of the bone; and in recent cases no dissection of the soft parts from the patella is necessary. It seems important that the cartilaginous surface of the bone should be left quite smooth, or, in other words, that the fragments should be exactly at the same level at their lower part. We cannot be perfectly sure, when we drill, that the bradawl will come out exactly at a corresponding point on the two surfaces. Supposing that on one side the instrument should have come out too far down, it may be into the cartilage (as at *d*, Fig. 2) instead of a little above it. We do not regard that at first, but pass the wire through each drill-hole the moment the drill is withdrawn, and then on that side on which the hole has come too far down, by means of the bradawl, we simply chip away a little of the material that is above the wire until the wire comes to be in a position exactly opposite to the hole on the other side, leaving a gap below, as indicated by the dark shade at *d*. This is a perfectly simple matter; at the same time, it might

possibly not occur to any one during the operation. Here (Fig. 3) we have the wire represented twisted, and the twist hammered down. The twist always goes to one side, and, being on the other side in this instance, is not shown in the section represented by the diagram.

I should like, gentlemen, with your permission, to make some few general remarks. I think it must be admitted that these cases show that the mode of treatment which I have recommended, when applied to recent transverse fractures of the patella, affords a means of restoring the joint to, practically, a perfectly natural condition, provided only that no disaster occurs. That, however, is a tremendous proviso, and no one is more conscious of it than myself. Before I made the incision in the first case that I have recorded to-night, I remarked to those who were assembled in the theatre that I considered no man justified in performing such an operation, unless he could say,

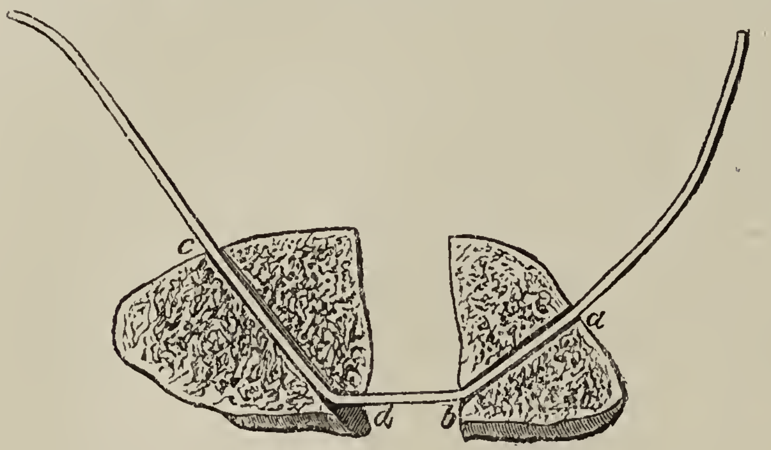

Fig. 2.

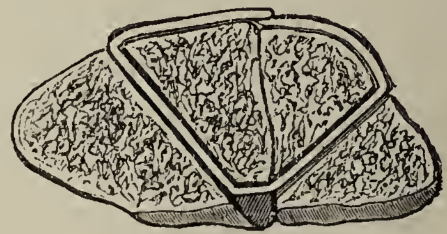

Fig. 3.

with a clear conscience, that he considered himself morally certain of avoiding the entrance of any septic mischief into the wound. Supposing, on the other hand, that a man can say that with a good conscience, then I conceive that he is not only justified, but bound to give his patient the advantages that we see are to be derived from this method of procedure. We know, of course, very well that, by ordinary means of treatment, patients often recover with exceedingly useful limbs. Every now and then, osseous union is obtained; it is a thing which I used to pride myself formerly on striving to get, and I have got such a thing, but it was rather rare, and it was obtained by a very tedious process; and, if ligamentous union occurred, we never had any security that what was a very short ligamentous union when the patient was discharged might not be a long ligamentous union at a later period. A gentleman consulted me with transverse fracture of the patella a couple of years ago. He happened to come to me just as I was about to start for my autumn holiday. I did not care to operate upon him, and throw the responsibility of the after-

treatment upon another, and it happened that the case seemed especially favourably circumstanced for osseous union. There was nothing between the fragments ; the two could be brought into apposition with the utmost facility. I applied an apparatus which appeared to have the effect of maintaining perfect immobility of the fragments ; and, when I came back from my holiday, I found them as I had left them, with no interval between them, and I hoped there might be osseous union. Eight weeks after the accident the patient was allowed to get up and walk, and I was told that he was walking exceedingly well. Six weeks after this, I asked him to come and report himself, and I was sorry to find that there was already half an inch of separation of the fragments. He was then about to start for India. What the separation may be now, I do not know. It is true that there may be a very useful knee-joint, with a very considerable length of fibrous union. Still, when there is a great length of fibrous union the knee is not equal to the original.

Some of our experience with these cases, where we had the opportunity of inspecting the actual state of things, will serve to explain the uncertainty of the results of ordinary treatment. We have found, for instance, such dense masses of clot so mixed with fibrous tissue as to make it quite impossible that the fragments should be brought into apposition. I found in one case, also, such a tilting up of one of the fragments that it would have been perfectly impossible to get the osseous surfaces in contact by any other means than direct operative procedure. Considering, therefore, the great inconvenience which results in many cases when the treatment is conducted on ordinary principles, I believe that if we can really say that we are morally certain that we do not subject the patient to risk, we are in duty bound to give him the benefit of this method. It has been said that it is not justifiable in recent cases, though it is justifiable in ununited cases where there is a useless limb. I must confess that if I believed I was subjecting a patient to serious risk to life, I should not feel justified in operating on the ununited case, and the ununited case is in every respect worse as a subject of operation than the recent. The ununited case has the fragments probably dwindled by absorption, and these fragments, already dwindled, have to be pared. There is a separation, it may be a very considerable separation, and this has to be overcome, it may be by dividing the quadriceps extensor, an operation of difficulty ; and in proportion to the length and difficulty of the operation is the chance that the surgeon may forget some point of importance with regard to the antiseptic element. Then, again, when you come to divide the quadriceps extensor, you divide a very vascular structure, and you may have haemorrhage ; and, further, when the fragments are brought into apposi-

tion they very likely are at considerable tension, and the tension may be apt to cause, through the nervous system, an inflammatory disturbance, and this tends to weaken the parts, and to diminish the power of resistance by which the natural tissues are able to combat the entrance of septic agencies, even though they be in contact with the part. With the recent case, on the other hand, everything is favourable. We have a wound involving no bleeding; and there is no need to pare the fragments. All you have to do is to sponge away the clots, and the surfaces are ready for coaptation. The drilling is a matter of the utmost simplicity. It is an operation of no difficulty, it does not take long; it does not cause anxiety to the surgeon; there is no shock to the system, and no tension. In every respect, the circumstances are favourable as regards the operative procedure. And then, when we come to consider the chances of successful antiseptic management, if there is in the whole body a situation which is well adapted for antiseptic treatment it is this; for of all the conditions requisite according to our present methods of procedure, that which is most important is that the skin on all sides round about the wound should be able to be amply overlapped by the antiseptic dressings. Here we have the wound in the middle of a long limb; from the groin to the foot we may have our antiseptic envelope. Then again we have this envelope surrounded with a secure bandage, and the bandaged dressing encased in a splint, and even if you come to have the patient delirious, as one of my patients was, or supposing a patient to be very curious, as some patients will be, it would puzzle him to get the wound exposed under these circumstances. Now there are wounds so circumstanced that you cannot well guard against this risk. I had a gentleman lately under my care with a psoas abscess; he was very intelligent, and seemed duly impressed with the importance of the antiseptic management; and yet his brother, who was a medical man, coming in one day, saw him drawing the dressing aside, and peeping at the wound. Now a man cannot peep at a wound in connexion with a fracture of the patella; it is so circumstanced mechanically that he cannot do it; and I believe that if we use the means that we have now at our disposal, we may say, with a safe conscience, if we use them aright, that we do not subject the patient to risk, not to anything like so great a risk as patients used to be subjected to not many years ago when they had fatty tumours removed in general hospitals in London. We must all of us remember cases in which, after such operations, erysipelas or diffuse suppuration came on, or some other 'unhealthy action', which, of course, was nobody's fault, but the patient died.

I have referred to a case of ununited fracture of the olecranon where

eighteen surgeons had been previously consulted. I trust no one here will suppose that I mentioned this circumstance for the purpose of glorifying myself. I mentioned it in order to emphasize what I believe to be the truth, that by antiseptic means we can do, and are bound to do, operations of the greatest importance for our patients' advantage, which, without strict antiseptic means, the best surgeon would not be justified in recommending. How wise those eighteen gentlemen were in counselling against operative interference, provided they were not prepared to operate strictly antiseptically, I think we must be all agreed. As regards the operative procedure in that case, it was of the most simple character; any first year's student could have done the operation exactly as well as myself; and, therefore, I trust I shall not be misunderstood by its being supposed that I came here to extol my own skill. That which justified me in operating in that case was simply the knowledge that strict antiseptic treatment would convert serious risk into complete safety.

I should have liked, if time had permitted, to have said a few words as to what seem to be the essential points as regards antiseptic treatment. If I say any words at all now, they will be exceedingly few. I should just like to make this remark, however, that nowadays antiseptic treatment is not a very complicated business, either in theory or in practice. First, as to theory, we do not require any scientific theory to enable us to believe in antiseptic treatment. You need not believe in the germ theory at all; if you are not convinced of the truth of the germ theory of putrefaction and of septic agencies generally, no matter whatsoever with reference to antiseptic practice. All that you have to believe is that there are such things as putrefaction and other septic agencies, and that our wounds are liable to these, and that they are very pernicious, and that these things come from without, and that we have the means of preventing them by various chemical agencies. That is all that we require; and I think anybody who knows the present state of surgical practice must admit these to be truisms. It has sometimes been a great grief to me to think that, because gentlemen are not convinced of the truth of the germ theory out and out, therefore they lay aside antiseptic treatment altogether. And then as to practice; it is not a very difficult thing to wash your hands in a carbolic solution, and have your instruments in this carbolic solution for a quarter of an hour before you operate. It is not a very difficult thing to wrap round the limb a suitable envelope of antiseptic material. What I believe to be one of the most important things of all is, strictly to maintain this rule inviolate, which I insist upon with my dressers, and which I confess I have insisted upon more of late years than I used, and that is,

always when we change a dressing, invariably first to cover the wound with something pure ; not to wash the surrounding parts with antiseptic solution, and then, after this has been done, put a dressing on the wound ; but before we begin to defile the lotion at all, put on the wound what is pure, and, last thing of all, wash the surrounding parts, which, though they look the same to our eyes, are different *toto coelo.* The edges of the dressing are septic ; the wound, if it is as it ought to be, is aseptic. I have known such a thing, for instance, as for a gentleman, in dressing a stump after amputation of the thigh, to wash the perineum with a rag dipped in the carbolic lotion one in forty ; and then, having so washed the perineum, immediately to squeeze the rag over the wound. Gentlemen, that makes you laugh ; but I assure you these are the kind of things that are constantly going on, and disasters happen in consequence ; and gentlemen with whom things go wrong invariably say that with them everything has been perfectly done—a thing which, for my part, I am always loath to say. I am not likely to have many more years of active surgical work ; and I have felt that when you, sir, gave me this opportunity, it was my duty to speak what I believe to be the truth ; for I feel it to be a grievous thing that patients should be hurried out of their lives, or deprived of usefulness of limbs, simply for want of sufficient earnestness with regard to the endeavour to obtain complete exclusion of septic agencies from wounds, according to our present lights and our present knowledge. Gentlemen, I thank you most heartily for your cheers ; for there was a time when such remarks might have met with a different reception.

REMARKS ON THE TREATMENT OF FRACTURES OF THE PATELLA OF LONG STANDING

[*British Medical Journal*, 1908, vol. i, p. 849, and *Lancet*, 1908, vol. i, p. 1049.]

SHORTLY before I retired from practice I devised a method of dealing with fractures of the patella of long standing which gave very satisfactory results. I failed to publish it at the time ; but a surgical friend having asked my advice in a case of that kind, I wrote for him a detailed description of the procedure, preserving a copy of my letter, which I venture, even at this late period, to reproduce.

Fisher's Hotel,
Pitlochry, Scotland.
September 15th, 1895.

My dear Dr. ———,

I should have written to you long ago regarding Miss ——'s case, had I not known that you could not deal with it till you had returned home after your autumn holiday in Europe ; Mr. —— having given me your address in London up to the 15th inst. The limb is no doubt useful as it is ; but it is very far from being as strong as we should wish to see it ; and assuming, as I do in your case, that the surgeon can look with confidence to an aseptic condition of the wound, I think an endeavour should be made to improve it. Indeed, there is good reason to believe that it will be made as serviceable as ever. I doubt, however, whether you will be able to bring the fragments together without some special mode of procedure. When you visited my wards in King's College Hospital, now several years ago, I showed you a young man on whom I had operated on account of a fracture of the patella of long standing with considerable separation of the fragments, where I had attained my object by means of free division of the quadriceps extensor muscle. This, however, is a pretty severe measure, and involves, at the best, more or less weakening of the muscle and a long cicatrix.

Since that time I have greatly improved on that practice, and have succeeded without touching the quadriceps by proceeding in two stages. The idea was suggested to me by a case published by Dr. Lucas-Championnière, of Paris, who, being unable to get the fragments into apposition, wired them together nevertheless, and left the wire in as an adjuvant connecting medium.

It occurred to me that, although such a use of the wire did not seem likely to be very satisfactory as a permanent arrangement, yet it might probably be adopted with great advantage as a temporary expedient ; and that, after the quadriceps had been gradually stretched by the use of the limb in the position so produced, the fragments might by a second operation be brought into contact, and might then be wired in the usual way after paring the opposed surfaces. The first case in which I put this idea in practice was a sufficiently testing one. The patient was a young woman of very stout and heavy build, who had fractured both patellae, one of them four years, the other three years before she consulted me. The fragments were, in both limbs, considerably separated ; and in the

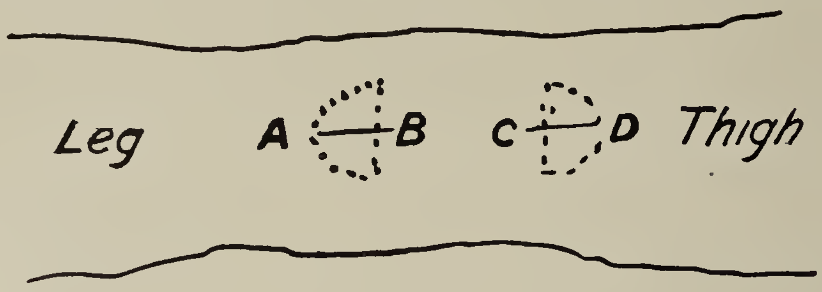

Fig. 1.

left, where the bone had been injured four years previously, the separation was so great (about 5 inches), and the upper fragment, at the same time, so very small, that I at first despaired of being able to do anything.

But on the right side, the upper fragment being of good size and the separation more moderate, I determined to give the plan a trial. I made two short longitudinal incisions (*A B* and *C D*) over the two fragments (shown in dotted line, Fig. 1), and having exposed them by a little dissection, drilled two holes in the upper one, and passed through them, from without inwards, the ends of a piece of the usual stout silver wire, so that, when the ends were pulled upon, the middle of the loop of wire would press upon the surface of the fragment, thus (Fig. 2) :—

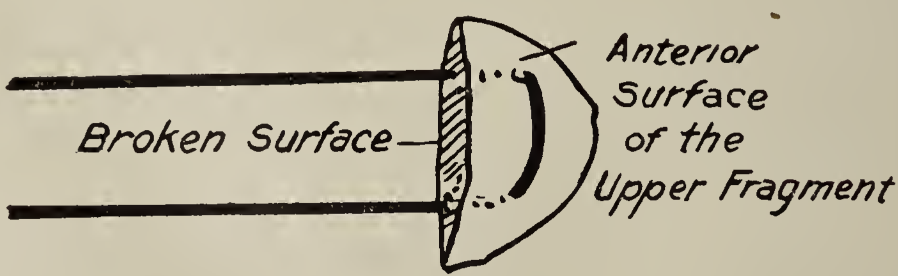

Fig. 2.

Next, passing into the lower incision a blunt instrument (a broad raspatory), I detached from the front of the femur the soft parts lying between the incisions,

consisting, of course, only of skin and fat, as the muscle was absent at that part. Then passing a strong pair of forceps from the lower incision under the skin till their blades appeared in the upper incision, I seized the ends of the wire and drew them down into the lower incision. I then drilled two holes in the lower fragment and passed the ends of the wire through them from within outwards, and, after drawing the upper fragment well down, secured them in the usual way and cut the ends short. The immediate result, so far as the fragments were concerned, is indicated in this diagram (Fig. 3). The incisions in the skin

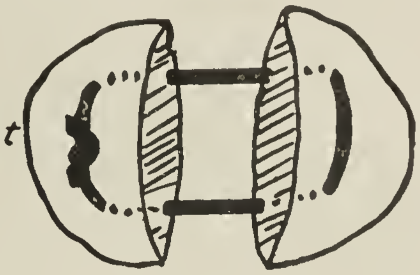

FIG. 3.

were then brought together by sutures, and a dressing (the double-cyanide gauze) applied.

In drawing down the upper fragment I found a great advantage from the use of a very strong sharp hook (Fig. 4), the point of which was inserted in the tendon of the quadriceps at its attachment. By this means I was able to exert much greater traction upon the bone than can be done by simply pulling upon the wire ; and, in order to relax the quadriceps as much as possible, the limb

FIG 4.

was placed in the vertical position before the fragment was pulled down. The dressing having been put on, a trough of Gooch's splint was applied to the limb still in the elevated position, and the same attitude was maintained as the patient was removed to the ward, and continued by attaching the end of the splint to a rope connected with the tripod and pulley used in applying Sayre's plaster-of-Paris jacket. This position of the limb did not cause the patient material inconvenience, and after two or three days the rope was slackened a little so as to allow the end of the splint to come down an inch or two, and the same

thing was repeated every two days or so, till the limb could be placed quite horizontal.

This preliminary operation has taken a long time to describe ; but in execution it is of the simplest character, no paring of the broken surfaces being done at this stage, and there being almost no bleeding and no shock. The wound having healed (I need hardly say without suppuration), the patient was allowed to leave her bed, and left the hospital soon after to practise using the limb.

Before long she was readmitted, and the second operation was performed. The lower cicatrix was opened and the wire removed, and two interrupted wire sutures placed in the tracks of the previous continued one ; the fragments, of course, being this time pared to clear them of fibrous tissue of new formation, and produce smooth surfaces for coaptation. This was all satisfactorily effected, though not without the use of the powerful hook and the vertical position of the limb. The result was restoration of the use of the joint in a manner so satisfactory that I determined to try the same procedure in the other limb. The only difference which I made in this case was that, as the upper fragment was too small to bear drilling, I passed the ends of the wire, in dealing with that fragment, through the tendon of the quadriceps just above the upper border of the bone, the lower fragment, which was, of course, very substantial, being drilled as in the other limb. By this means, aided by the vertical position of the limb and the hook, I was able to bring down the upper fragment very satisfactorily, so much so that I did not feel it needful to have the patient use the limb in walking before proceeding to the second operation, but did this before she left her bed, soon after the wounds had healed. In the second operation I applied two interrupted sutures, passing them, as in the first operation, through the track in tendon and bone which the first wire had occupied.

The continued wire suture, which was first used by Dr. Hector C. Cameron, of Glasgow, has the great advantage, where much traction has to be made upon the fragments, that the pressure of the wire is distributed over the anterior surface of the bone instead of being concentrated upon the limited portion of tissue included in an interrupted stitch. And this is peculiarly valuable in old cases of fracture ; in which, as a result of long disuse, the bone undergoes interstitial atrophy that sometimes makes it very soft. But this suture has the disadvantage that it may tilt the fragments so that their anterior edges do not come well into contact with each other, as indicated in this diagram (Fig. 5).

This was my reason for preferring the interrupted suture in the second stage of the proceeding. In the first stage, in which the principal dragging probably takes place, this circumstance is a matter of no consequence, as accurate apposition of the fragments is not then aimed at ; and in any case admitting of being

dealt with by a single operation, though not without much traction, this defect of the continued suture might be readily got over by introducing a superficial central stitch of comparatively thin wire to ensure coaptation of the anterior margins of the fragments.

The effect of the second operation in the above case was such as would have surprised me if I had not seen in other cases how substantial and strong a patella may result from wiring after thorough paring of the surfaces, even when one of the fragments is of quite insignificant size. Without my notes I cannot say how long it is since the case was treated, but I think it must be about four years. And I lately had the satisfaction of hearing from the patient that she could walk well, with strong and supple knee-joints.

FIG 5.

In Miss ——'s case I would suggest that you should, in the first instance, before making any incision, but after she has been placed under an anaesthetic, apply the strong sharp hook to the border of the upper fragment through the skin, and, with the limb vertical, ascertain to what extent the quadriceps will yield immediately. If the upper fragment came pretty well down, you would proceed to do all by one operation, but if there were the slightest doubt as to the feasibility of this, you would adopt the preliminary procedure as in the above case.

Supposing you to be doing all by one operation, and that it seems desirable to employ Cameron's continued suture, as the wire will be left in permanently, it would be better to introduce its ends first into the lower fragment and fix them over the upper one, where the fixed ends could not cause inconvenience in kneeling. The strong hook would keep the upper fragment well down during the fixing process. If I had published this case, as I ought perhaps to have done, I should not have had to inflict upon you so large an amount of manuscript.

I remain,

Ever truly yours,

(Signed) JOSEPH LISTER.

PART V

ADDRESSES

AN INTRODUCTORY LECTURE

(ON THE CAUSATION OF PUTREFACTION AND FERMENTATION)[1]

Delivered in the University of Edinburgh, November 8, 1869.

[Edinburgh, 1869 (Pamphlet).]

GENTLEMEN.—I stand before you affected with very mingled feelings. On the one hand, I cannot but feel proud to have been called to occupy a Chair which, without disparagement to others, must be allowed to have been, during the last thirty-six years, the one most influential for good in this the most important medical school in the British dominions. But the exultation which I might otherwise naturally feel is heavily dashed by the thought that the circumstance which led to my promotion was the retirement of the man to whom the lustre of the Edinburgh Chair of Clinical Surgery has been from first to last entirely due. I am well aware that he has made the place, not the place him. And though in his presence I must not say all that I otherwise should, I cannot refrain from expressing my conviction that, whether regarded as a scientific and practical surgeon, or as a teacher of those principles which he has done more than any other man in this century to establish, he has been without a rival in the world. Hence, in addition to the grief which I feel in common with you all at the cause of his resigning the Chair which he had so long adorned, I am oppressed with a humbling sense of my own insufficiency ; of my weakness, compared with his giant strength of mind and purpose ; of my utter inability to fill his place. I can only strive, by the blessing of God, to do my best among you, relying, as I know I may, upon your generous sympathy. At the same time, we may all rejoice that our old master is still among us, to cheer us by his presence and aid us by his counsel ; and it is a source of great satisfaction to myself that, as I have the privilege of free access to his inexhaustible store of wisdom and experience, he will, in some sense, through me be still your teacher.

[1] This lecture was not originally intended for publication, and was for the most part delivered extempore.

But, leaving these personal considerations, let us turn to the subject that lies before us. Clinical surgery is, strictly speaking, surgery at the bed-side; surgery illustrated by cases in hospital, as distinguished from surgery taught systematically in the class-room. The importance of clinical or bedside study cannot be overestimated. It is the very keystone, without which all the rest of the educational structure, being merely preparatory, would be absolutely useless. It is to surgery or medicine what dissection is to anatomy. It confers a familiar acquaintance with the nature of disease, and an instinctive knowledge of the appropriate treatment, without which, a man, however accomplished otherwise, would be utterly unfit to practise the profession. But how, it may be asked, can a course of lectures be delivered upon this principle? Can it be possible to take a class of the size of my present audience from bed to bed in a ward, and profitably teach them there? To do this would certainly be impossible. Remarks made at the bed-side are doubtless highly valuable to those who hear them and who see their subject; but it is only a few at a time who can be thus taught. Hence clinical lectures commonly degenerate into the reading of details of cases, with remarks upon them, which, for the great majority of those who hear them, lack the genuine element of clinical interest.

This difficulty was happily overcome by Mr. Syme. Though it was impossible to take a large class to the bed-side of the patient, it was easy in most instances to bring the patient before the class, collected in the operating theatre, where they could all see the salient features of the case, and hear not only the remarks of the teacher, but the patient's own account of his symptoms, and witness the treatment then and there put in practice; or, if it was thought desirable to defer the operation to another day, they were prepared to watch its various steps with intelligence and profit, after having heard the principles of the procedure fully discussed. Such a course of instruction is truly clinical, and, if rightly conducted, possesses a vividness of interest and permanence of impression peculiar to itself. Having witnessed its advantages when in Edinburgh, I have followed this system in Glasgow, and shall continue to pursue it here. But invaluable as such lectures may be made, you must not suppose that attendance upon them will do all that is needful for you in the way of clinical study. You must not only see diseases and watch their treatment by others, but handle them and be personally concerned in their management. Facilities for this are presented by the hospital offices of dresser, clerk, and house surgeon, and no man should consider himself justified in assuming the serious responsibilities of practice without having availed himself largely of such opportunities, either in our infirmary or in some other similar institution.

But to return to the course before us. There are some details regarding the mode in which you may attend it to the greatest advantage, which I shall reserve till we next meet. And now, as the place where we are assembled forbids my entering at once upon demonstrative surgery, I propose to devote the remainder of this hour to the endeavour to convince you, so far as the limited time at our disposal permits, of the truth of the germ theory of putrefaction, the basis of a new mode of treatment which finds its application in all departments of practice ; so that without understanding it we cannot advance satisfactorily in the consideration of individual cases. I allude to the antiseptic system. This system of treatment consists of such management of a surgical case as shall effectually prevent the occurrence of putrefaction in the part concerned. When this is really secured, surgery becomes something totally different from what it used to be ; and injuries and diseases formerly regarded as most formidable, or even hopeless, advance quietly and surely towards recovery. Of this system the germ theory of putrefaction is the pole-star which will guide you safely through what would otherwise be a navigation of hopeless difficulty.

The germ theory declares that the putrefaction of organic substances under atmospheric influence is not effected, as used to be supposed, by the oxygen of the air, but by living organisms developed from germs floating in the atmosphere as constituents of its dust.

The first great step towards the establishment of this theory was the discovery of the yeast plant in 1838 by Cagniard-Latour, who, having detected in yeast a microscopic fungus, the *Torula Cerevisiae,* which appeared to be the essential constituent of the ferment, attributed the resolution of sugar into alcohol and carbonic acid to the disturbing influence of the growing organism.[1] In the following year, Schwann of Berlin published the results of a remarkable investigation into the cause of putrefaction (in the course of which, by a coincidence such as is not uncommon in the history of science, he, too, had independently discovered the yeast plant), and he related experiments which showed that a decoction of meat might remain for weeks together free alike from putrefaction and from the development of infusoria or fungi in a flask containing air frequently renewed, provided that the atmosphere was subjected to a high temperature at some part of its course towards the containing vessel.[2] Hence he concluded that putrefaction was caused by the growth of organisms springing from germs in the air, the heat preventing the putrefactive change by depriving the germs of their vitality. In other words, he propounded the

[1] See *Comptes Rendus*, tom. iv, p. 905.
[2] See Poggendorf's *Annalen*, vol. xli, art. xvi.

germ theory of putrefaction. These experiments of Schwann's appear to me to prove conclusively that oxygen, as ordinarily understood by chemists, cannot of itself occasion putrefaction. It is true, indeed, that, if you attempt to repeat the experiments, you may meet with failure. But it must be remembered that merely negative results go for nothing here, if the positive evidence rests on satisfactory authority. This is a point which has been too little borne in mind in the discussion of this subject. If we consider what the germ theory assumes, how minute the putrefactive particles are supposed to be, and how universally present in the atmosphere, and in the dust which adheres to all objects exposed to it, it is easy to understand failure in such experiments consistently with the truth of the theory. But it is *impossible* to understand success in any single instance, consistently with the falsehood of the theory. If in any one case it really happened that a decoction of meat remained without putrefaction for weeks together, though freely exposed to air, unaltered, except by having been temporarily subjected to a high temperature, this is enough to show that oxygen, as known to chemists, is not the sole cause of the change in question.[1] One genuine successful experiment out of a thousand is enough to establish that point.

Schwann's observations, however, did not receive the attention which they appear to me to have deserved. The fermentation of sugar was generally allowed to be occasioned by the *Torula Cerevisiae*; but it was not admitted that putrefaction was due to an analogous agency. And yet the two cases present a very striking parallel. In each a stable chemical compound, sugar in the one case, albumen in the other, undergoes extraordinary chemical changes under the influence of an excessively minute quantity of a substance which, regarded chemically, we should suppose inert. As an example of this in the case of putrefaction, let us take a circumstance often witnessed in the treatment of large chronic abscesses. In order to guard against the access of atmospheric air, we used to draw off the matter by means of a cannula and trocar, such as you see here, consisting of a silver tube with a sharp-pointed steel rod fitted into it, and projecting beyond it. The instrument, dipped in oil, was thrust into the cavity of the abscess, the trocar was withdrawn, and the pus flowed out through the cannula, care being taken by gentle pressure over the part to prevent the possibility of regurgitation. The cannula was then drawn out with due precaution against the reflux of air. This method was frequently successful as to its immediate object, the patient being relieved

[1] Such experiments are peculiarly likely to fail in the hands of those who perform them with the object of confuting the germ theory. In fact, a belief in the theory is almost essential in order that the experimenter may be sufficiently keenly alive to the subtle sources of failure

from the mass of the accumulated fluid, and experiencing no inconvenience from the operation. But the pus was pretty certain to reaccumulate in course of time, and it became necessary again and again to repeat the process. And unhappily there was no absolute security of immunity from bad consequences. However carefully the procedure was conducted, it sometimes happened, even though the puncture seemed healing by first intention, that feverish symptoms declared themselves in the course of the first or second day, and, on inspecting the seat of the abscess, the skin was perhaps seen to be red, implying the presence of some cause of irritation, while a rapid reaccumulation of the fluid was found to have occurred. Under these circumstances, it became necessary to open the abscess by free incision, when a quantity, large in proportion to the size of the abscess, say, for example, a quart, of pus escaped, fetid from putrefaction. Now, how had this change been brought about ? Without the germ theory, I venture to say, no rational explanation of it could have been given. It must have been caused by the introduction of something from without. Inflammation of the punctured wound, even supposing it to have occurred, would not explain the phenomenon. For mere inflammation, whether acute or chronic, though it occasions the formation of pus, does not induce putrefaction. The pus originally evacuated was perfectly sweet, and we know of nothing to account for the alteration in its quality but the influence of something derived from the external world. And what could that something be ? The dipping of the instrument in oil, and the subsequent precautions, prevented the entrance of oxygen. Or even if you allowed that a few atoms of the gas did enter, it would be an extraordinary assumption to make that these could in so short a time effect such changes in so large a mass of albuminous material. Besides, the pyogenic membrane is abundantly supplied with capillary vessels, through which arterial blood, rich in oxygen, is perpetually flowing ; and there can be little doubt that the pus, before it was evacuated at all, was liable to any action which the element might be disposed to exert upon it.

On the oxygen theory, then, the occurrence of putrefaction under these circumstances is quite inexplicable. But if you admit the germ theory, the difficulty vanishes at once. The cannula and trocar having been lying exposed to the air, dust will have been deposited upon them, and will be present in the angle between the trocar and the silver tube, and in that protected situation will fail to be wiped off when the instrument is thrust through the tissues. Then when the trocar is withdrawn, some portions of this dust will naturally remain upon the margin of the cannula, which is left projecting into the abscess, and nothing is more likely than that some particles may fail to be washed off

by the stream of outflowing pus, but may be dislodged when the tube is taken out, and left behind in the cavity. The germ theory tells us that these particles of dust will be pretty sure to contain the germs of putrefactive organisms, and if one such is left in the albuminous liquid, it will rapidly develop at the high temperature of the body, and account for all the phenomena.

But striking as is the parallel between putrefaction in this instance and the vinous fermentation, as regards the greatness of the effect produced, compared with the minuteness and the inertness, chemically speaking, of the cause, you will naturally desire further evidence of the similarity of the two processes. You can see with the microscope the torula of fermenting must or beer. Is there, you may ask, any organism to be detected in the putrefying pus ? Yes, gentlemen, there is. If any drop of the putrid matter is examined with a good glass, it is found to be teeming with myriads of minute jointed bodies, called vibrios, which indubitably proclaim their vitality by the energy of their movements. It is not an affair of probability, but a fact, that the entire mass of that quart of pus has become peopled with living organisms as the result of the introduction of the cannula and trocar ; for the matter first let out was as free from vibrios as it was from putrefaction. If this be so, the greatness of the chemical changes that have taken place in the pus ceases to be surprising. We know that it is one of the chief peculiarities of living structures that they possess extraordinary powers of effecting chemical changes in materials in their vicinity, out of all proportion to their energy as mere chemical compounds. And we can hardly doubt that the animalcules which have been developed in the albuminous liquid, and have grown at its expense, must have altered its constitution, just as we ourselves alter that of the materials on which we feed.

The only question, therefore, that remains to be answered is, Whence have these vibrios originated ? Have they sprung, like higher animals and plants, from pre-existing similar organisms, or have they arisen spontaneously out of the pus from an alteration in its physical constitution, determined in some inexplicable manner by the introduction of a cannula and trocar ?

All analogy, gentlemen, is in favour of the former view. The doctrine of spontaneous or equivocal generation has been chased successively to lower and lower stations in the world of organized beings, as our means of investigation have improved. I remember a conversation I once had, when a student, with an elderly gentleman, not indeed belonging to our profession, on the subject of mites in cheese. He believed that they grew out of the cheese from some change in its substance as the result of keeping ; and the view which I advocated, that they had sprung from the eggs of pre-existing mites, seemed

to him preposterous. But when the microscope is applied to these creatures, and we see that they rank in the type of their organization with spiders or crabs, and that they are similarly provided with organs of reproduction, it seems to us as absurd to suppose that they have arisen from a mere alteration in the cheese as it would be to imagine that crabs could spring spontaneously out of a piece of dead fish or other garbage upon which they prey. Yet though no physiologist doubts that cheese-mites do arise from parentage, it must be confessed that there is some difficulty in accounting for their almost invariable occurrence in some kinds of cheese kept for a sufficient length of time. Whether the eggs are transferred by the hand of the cheesemonger, or whether the adult mites migrate from cheese to cheese, may be matter for curious discussion.

But though with creatures as large, comparatively speaking, as the cheese-mite, it may not be very easy to explain the extensive diffusion of their ova, this difficulty becomes less and less the more minute the organism. If a vessel containing preserved fruit is left exposed to the air, the surface of the preserve soon becomes covered with mould, and it is then found to have a 'mouldy' flavour—implying alteration in its chemical constitution. The mould itself has a flavour of its own, and it has developed, in part at least, at the expense of the preserve. If the mould is examined microscopically, it is seen to be just as distinctly a vegetable as a cabbage is, and far more abundantly provided with reproductive apparatus. Supposing it to be the ordinary blue mould, the blue tint is simply the colour of the fructification. This is in accordance with a general law in the organic world, that so far from any deficiency appearing in the arrangements for reproduction in the lower forms of life, so as to make it difficult to account for their originating from parents, the lower the organism the more lavishly is this provided for. In some animals low in the scale of being we find, besides the formation of ova, a faculty of self-multiplication by segmentation, or, as it is termed, fissiparous generation. For what purpose, I venture to ask, can be this ample provision for reproduction of the lowest species by parentage, if they can spring spontaneously out of the materials in which they grow?

Now, in the case of the blue mould, the sporules, besides being produced in incalculable multitudes, are of extreme minuteness, and constitute a very fine dust, which cannot fail to be wafted and extensively diffused through the air. If a ray of sunlight were to shoot through this room, we should see the sunbeam peopled with motes. But the particles of dust which are rendered visible to the naked eye by being so illuminated, are gross indeed compared with the sporules of such a fungus. Some of them are complicated organic

structures, such as pieces of hair or vegetable fibre ; and if these are suspended in the air, still more must microscopic spores be so, though their extreme minuteness makes it less easy to distinguish them from particles of inorganic matter. Hence it appears that, for the lowest forms of life, as for the highest the notion of spontaneous generation is simply gratuitous and uncalled for.

But although from these considerations we may be led pretty surely to infer, on the one hand, that the atmosphere is pervaded by the germs of minute organisms, and, on the other hand, that without such germs the organisms could not take their origin, it would be highly desirable to obtain positive evidence on both these points, if indeed it is attainable.

Such evidence has been afforded of late years by the beautiful researches of Pasteur. From among his numerous experiments, I will select one set as peculiarly instructive. A number of glass flasks, with attenuated necks, were partially filled with a decoction of yeast, filtered so as to be perfectly clear and transparent. Each was then boiled for a certain length of time, with the object of destroying any organisms existing in the decoction, or adhering to the interior of the vessel, and during ebullition the neck was hermetically sealed, so that when the vessel cooled, a vacuum was produced in the part previously occupied by air. A certain number of such a series of flasks were then opened in a particular locality, as, for example, a lecture-room such as this, by breaking the narrow neck of each, after scratching it with a file. Air rushed in to fill the vacuum, after which the neck was immediately sealed again with the blow-pipe. As the result of the introduction of this limited amount of air, the previously transparent liquid in a considerable proportion of the flasks was seen to present, in the course of the next few days, a cloudiness indicative of the first appearance of the growth of torulae and other organisms, which afterwards continued to increase. But if a set of such flasks were opened in a situation where atmospheric germs might be expected to be few, if any, a different result was obtained. M. Pasteur was at the pains to take such flasks to the Mont Anvert, in Switzerland, and open them in wind blowing from a glacier, taking special care, by exposing the neck to the flame of a spirit-lamp when filing it, and breaking it with long forceps similarly treated, to guard as much as possible against the introduction of living organisms from the instruments employed, or from his own person. The pure air thus introduced had indeed, in one flask out of twenty, the effect of inducing, very slowly, an appearance of organic development. But in all the rest the liquid remained perfectly unchanged for an indefinite period. On the other hand, if the flasks were opened in a situation where the air, though in one sense pure, might be expected to abound in minute life, viz. under the shade

of trees in the country, organisms formed in sixteen out of eighteen flasks, and presented a great variety in their nature.[1] These experiments, which rest not only on the high authority of M. Pasteur, but also on the unimpeachable corroborative testimony of a Committee of the French Academy of Sciences, including the celebrated Milne Edwards, prove conclusively both that the gases of the air cannot of themselves occasion the growth of organisms, even in a very favourable nidus for their development, and also that in regions inhabited by plants or animals, whether in cities or in the country, nearly every cubic inch of atmosphere really does contain living germs floating in it.

But there is one other experiment related by Pasteur,[2] which is in some respects even more striking. A flask is prepared similar to those already described, except that, after the introduction of the decoction of yeast, the neck is not only drawn out into a pretty narrow tube, but bent at various angles. The fluid is then boiled as in the former experiments; but the end of the neck, instead of being sealed, is left open, so that air passes into the flask on withdrawal of the lamp. The vessel being then left undisturbed, the diurnal changes of temperature, involving alternate expansion by day and condensation at night of the gases in the flask, necessitate a daily interchange between the air in the body of the flask and the external atmosphere. Yet the fluid, though exposed in this way to air perpetually changed, remains for an indefinite period quite transparent, without trace of organic development. There can be but one interpretation of this fact. The oxygen, whether in its ordinary condition or that of ozone, with all the other atmospheric gases, including any which may exist in such small quantities as to be undiscoverable by the chemist, must pass, each in its own proportion, unchanged into the body of the flask. It is impossible that a dry glass tube can stop any gas. For though the tube is moist from condensation of aqueous vapour in the first instance, it is soon dried by the air that passes in and out through it. It is, therefore, inconceivable that any atmospheric gas can have been arrested by the tube. But it is conceivable, considering the very gradual character of the movements of the air in consequence of the diurnal changes, that dust, even though very fine, may be arrested by the angles. We may, perhaps, wonder that particles of such extreme minuteness as the germs of atmospheric organisms should be so detained. But no one can say it is impossible, and no other possible explanation presents itself. The experiment proves with certainty that the gases of the air, however abundantly supplied, are of themselves unable to originate the growth of torulae and the other minute organisms which appear in decoction of yeast

[1] See *Annales des Sciences Naturelles*, 1861 and 1865.

[2] This experiment is attributed by Pasteur to M. Chevreul.

freely exposed to the atmosphere; and also that the essential source of such development must be suspended particles or germs. But in order to render the experiment, if possible, still more conclusive, the Committee of the Academy completed it by sealing the end of the neck of the flask, after the fluid had remained clear for a sufficient length of time to show that no organisms could grow in it, and inverting and shaking the vessel till some of the liquid passed into the angles of the bent tube, after which the flask was again left to itself. And now, gentlemen, occurred something which you may perhaps be disposed to regard as too good to be true, but which is true nevertheless. In the course of no long time the fluid in the angles of the tube exhibited indications of organic growth, demonstrating that the sources or germs of such development had, as a matter of fact, been arrested there.

This experiment charms us alike by its simplicity and perfect conclusiveness. Here is evidence indeed, which, if the facts be admitted, cannot be gainsaid. But though I could not doubt the authority on which it rested, I felt desirous, if possible, to bring it to bear more directly upon the subject of putrefaction. The fluid which seemed most likely to answer the purpose, combining transparency with a high degree of putrescibility, was urine, and I accordingly made it the subject of the experiment to which I now desire to direct your attention.[1] Two years ago last month, I introduced portions of the same specimen of fresh urine into four flasks, of which two are before you. The body of each vessel was about one-third filled with the liquid. After the introduction of the fluid, the necks of three of them were drawn out into tubes rather less than a line in diameter, and then bent at various acute angles, as you observe in one of these. In the other the neck was drawn out to a calibre if anything rather finer, but cut short and left vertical, as you see it. The liquid in each flask was then boiled for five minutes, the steam issuing freely from the open end of the narrow neck. The reason for boiling it so long is that, as Pasteur has shown, merely raising this fluid to the temperature of 212° Fahr., and then allowing it to cool, is not enough to kill all the organisms it may contain. It is necessary to maintain the elevated temperature for about five minutes to ensure complete destruction of their vitality.[2] The lamp being then removed, air of course passed in to take the place of the condensed aqueous vapour. And during the two years that have since

[1] Since making the experiment I have learned that Pasteur had previously performed it with urine.

[2] See *Comptes Rendus*, vol. l, p. 306. It follows that if any germs were drawn into the body of the flask with the air that rushes in on the withdrawal of the lamp, they would retain their vitality in the hot liquid, and develop in it when it had cooled. I have elsewhere expressed the opinion that the germs contained in the air which is thus rapidly admitted in the first instance must be arrested by the drops of water which appear in the angles of the tube immediately on the cessation of ebullition, just as the particles of dust in inspired air are stopped by the mucus of our bronchial tubes. See *British Medical Journal*, July 18, 1868 (page 58 of this volume).

elapsed, a considerable fraction of a cubic inch of fresh air has entered every night into the body of each flask to exert its influence upon the liquid. In the case of the flasks with contorted neck, the air moving to and fro through the tube soon dried the moisture which was at first deposited within it ; and any of you may see, after lecture, that in the one before you the neck is dry as well as open from end to end, so that it could present no obstacle to any gaseous constituent of the atmosphere. Nevertheless, though thus freely exposed to the action of the gases of the air for so long a period, including two unusually hot summers, the urine still retains its original straw colour and perfect transparency, presenting neither cloud, scum, nor sediment ; and the only change that I can detect in it is, that of late, as a result, I presume, of the slow evaporation that has been going on in consequence of the perpetual change of air, some very minute shining crystals have been deposited upon the sides of the glass. Similarly unaltered are the contents of the other two similar flasks which I have not thought it needful to bring here. But very different is the appearance of the urine in this other flask, whose neck, short and vertical, was calculated to admit particles of dust as well as gaseous material. The transparent straw colour has given place to a muddy brown, with abundant sediment, including the *débris* of different fungi, which have long since ceased to grow, poisoned, no doubt, by the acridity of the liquid, the pungently ammoniacal character of which may be readily ascertained by placing the warm hand for a moment upon the body of the flask, while one nostril is kept above the orifice.

Soon after the commencement of the experiment, this short-necked flask had a really beautiful appearance. Two different kinds of fungi presented themselves—one of exceedingly delicate structure growing rapidly from the bottom of the vessel, so as to occupy in no long time the greater part of the bulk of the liquid ; the other a dense blue mould floating at the surface, and extending slowly in concentric rings. Meanwhile the fluid gradually assumed a deeper and deeper amber tint, indicative of progressive change in its chemical composition.

In the case of the flasks with bent necks I was not content with observing the completely unchanged appearance of the contained urine. Half a year after the experiment was begun I poured out about half an ounce of the clear contents of one of them into a wine-glass for examination. Its odour was perfectly sweet, and its reaction faintly acid ; and under the microscope a careful search with an excellent glass of high power failed to detect vibrio, bacterium, or any other organism. The lowest known forms of organic development and the slightest approach to putrefactive change had been alike prevented by simply filtering the air of its floating molecules.

Yet the urine which had so long remained unaltered under the free influence of the gaseous constituents of the atmosphere proved as prone as ever to the usual effects of exposure to the air as soon as particles of dust could gain access to it ; for the wine-glass having been covered to prevent evaporation, I found the fluid in two days with a dunghill odour, and loaded with minute microscopic organisms, and a few days later different kinds of fungi visible to the naked eye were growing in it.

Gentlemen, I commend these facts to your candid and impartial judgement, beseeching you to form your own opinions regarding them. The minds which you bring to bear upon this subject to-day are very much the same as they will be throughout your lives. An observation which any one of you may make now will serve in after life to illustrate a course of lectures, should he occupy a position corresponding to that which I have now the honour to hold. And you are as competent as you ever will be to draw logical inferences from established data. Do not, then, let any authority shake your confidence in knowledge so obtained.

Throughout the course on which we are entering I shall endeavour, as far as possible, to place before you simple facts—trusting that, in estimating their significance, you will be ever guided by that which our dear master has so constantly striven to inculcate as our leading principle, the love of Truth.

ON THE INTERDEPENDENCE OF SCIENCE AND THE HEALING ART

Being the Presidential Address to the British Association for the Advancement of Science Liverpool, 1896.

[*Report of the Association.*]

My Lord Mayor, My Lords, Ladies, and Gentlemen.—I have first to express my deep sense of gratitude for the great honour conferred upon me by my election to the high office which I occupy to-day. It came upon me as a great surprise. The engrossing claims of surgery have prevented me for many years from attending the meetings of the Association, which excludes from her sections medicine in all its branches. This severance of the art of healing from the work of the Association was right and indeed inevitable. Not that medicine has little in common with science. The surgeon never performs an operation without the aid of anatomy and physiology ; and in what is often the most difficult part of his duty, the selection of the right course to follow, he, like the physician, is guided by pathology, the science of the nature of disease, which, though very difficult from the complexity of its subject-matter, has made during the last half-century astonishing progress ; so that the practice of medicine in every department is becoming more and more based on science as distinguished from empiricism. I propose on the present occasion to bring before you some illustrations of the interdependence of science and the healing art ; and the first that I will take is perhaps the most astonishing of all results of purely physical inquiry—the discovery of the Röntgen rays, so called after the man who first clearly revealed them to the world. Mysterious as they still are, there is one of their properties which we can all appreciate—their power of passing through substances opaque to ordinary light. There seems to be no relation whatever between transparency in the common sense of the term and penetrability to these emanations. The glasses of a pair of spectacles may arrest them, while their wooden and leathern case allows them to pass almost unchecked. Yet they produce, whether directly or indirectly, the same effects as light upon a photographic plate. As a general rule, the denser any object is the greater obstacle does it oppose to the rays. Hence, as bone is denser than flesh, if the hand or other part of the body is placed above the sensitive film enclosed in a case of wood or other light material at a suitable distance from the source of the rays, while they pass with the utmost facility through the uncovered parts of the lid of the box and powerfully affect the plate beneath, they are arrested to a large

extent by the bones, so that the plate is little acted upon in the parts opposite to them, while the portions corresponding to the muscles and other soft parts are influenced in an intermediate degree. Thus a picture is obtained in which the bones stand out in sharp relief among the flesh, and anything abnormal in their shape or position is clearly displayed.

I need hardly point out what important aid this must give to the surgeon. As an instance, I may mention a case which occurred in the practice of Mr. Howard Marsh. He was called to see a severe injury of the elbow, in which the swelling was so great as to make it impossible for him by ordinary means of examination to decide whether he had to deal with a fracture or a dislocation. If it were the latter, a cure would be effected by the exercise of violence which would be not only useless but most injurious if a bone was broken. By the aid of the Röntgen rays a photograph was taken in which the bone of the upper arm was clearly seen displaced forwards on those of the forearm. The diagnosis being thus established, Mr. Marsh proceeded to reduce the dislocation; and his success was proved by another photograph which showed the bones in their natural relative position.

The common metals, such as lead, iron, and copper, being still denser than the osseous structures, these rays can show a bullet embedded in a bone or a needle lodged about a joint. At the last conversazione of the Royal Society, a picture produced by the new photography displayed with perfect distinctness through the bony framework of the chest a halfpenny low down in a boy's gullet. It had been there for six months, causing uneasiness at the pit of the stomach during swallowing; but whether the coin really remained impacted, and if so, what was its position, was entirely uncertain till the Röntgen rays revealed it. Dr. Macintyre, of Glasgow, who was the photographer, informs me that when the presence of the halfpenny had been thus demonstrated, the surgeon in charge of the case made an attempt to extract it, and although this was not successful in its immediate object, it had the effect of dislodging the coin; for a subsequent photograph by Dr. Macintyre not only showed that it had disappeared from the gullet, but also, thanks to the wonderful penetrating power which the rays had acquired in his hands, proved that it had not lodged further down in the alimentary passage. The boy has since completely recovered.

The Röntgen rays cause certain chemical compounds to fluoresce, and emit a faint light plainly visible in the dark; and if they are made to fall upon a translucent screen impregnated with such a salt, it becomes beautifully illuminated. If a part of the human body is interposed between the screen and the source of the rays, the bones and other structures are thrown in shadow

upon it, and thus a diagnosis can be made without the delay involved in taking a photograph. It was in fact in this way that Dr. Macintyre first detected the coin in the boy's gullet. Mr. Herbert Jackson, of King's College, London, early distinguished himself in this branch of the subject. There is no reason to suppose that the limits of the capabilities of the rays in this way have yet been reached. By virtue of the greater density of the heart than the adjacent lungs with their contained air, the form and dimensions of that organ in the living body may be displayed on the fluorescent screen, and even its movements have been lately seen by several different observers.

Such important applications of the new rays to medical practice have strongly attracted the interest of the public to them, and I venture to think that they have even served to stimulate the investigations of physicists. The eminent Professor of Physics in the University College of this city (Professor Lodge) was one of the first to make such practical applications, and I was able to show to the Royal Society at a very early period a photograph, which he had the kindness to send me, of a bullet embedded in the hand. His interest in the medical aspect of the subject remains unabated, and at the same time he has been one of the most distinguished investigators of its purely physical side.

There is another way in which the Röntgen rays connect themselves with physiology, and may possibly influence medicine. It is found that if the skin is long exposed to their action it becomes very much irritated, affected with a sort of aggravated sun-burning. This suggests the idea that the transmission of the rays through the human body may be not altogether a matter of indifference to internal organs, but may, by long-continued action, produce, according to the condition of the part concerned, injurious irritation or salutary stimulation.

This is the jubilee of Anaesthesia in surgery. That priceless blessing to mankind came from America. It had, indeed, been foreshadowed in the first year of this century by Sir Humphrey Davy, who, having found a toothache from which he was suffering relieved as he inhaled laughing gas (nitrous oxide), threw out the suggestion that it might perhaps be used for preventing pain in surgical operations. But it was not till, on the 30th of September, 1846, Dr. W. T. G. Morton, of Boston, after a series of experiments upon himself and the lower animals, extracted a tooth painlessly from a patient whom he had caused to inhale the vapour of sulphuric ether, that the idea was fully realized. He soon afterwards publicly exhibited his method at the Massachusetts General Hospital, and after that event the great discovery spread rapidly over the civilized world. I witnessed the first operation in England under ether. It was performed by Robert Liston in University College Hospital, and it was a complete success. Soon afterwards I saw the same great surgeon amputate

the thigh as painlessly, with less complicated anaesthetic apparatus, by aid of another agent, chloroform, which was being powerfully advocated as a substitute for ether by Dr. (afterwards Sir James Y.) Simpson, who also had the great merit of showing that confinements could be conducted painlessly, yet safely, under its influence. These two agents still hold the field as general anaesthetics for protracted operations, although the gas originally suggested by Davy, in consequence of its rapid action and other advantages, has taken their place in short operations, such as tooth extraction. In the birthplace of anaesthesia ether has always maintained its ground ; but in Europe it was to a large extent displaced by chloroform till recently, when many have returned to ether, under the idea that, though less convenient, it is safer. For my own part, I believe that chloroform, if carefully administered on right principles, is, on the average, the safer agent of the two.

The discovery of anaesthesia inaugurated a new era in surgery. Not only was the pain of operations abolished, but the serious and sometimes mortal shock which they occasioned to the system was averted, while the patient was saved the terrible ordeal of preparing to endure them. At the same time the field of surgery became widely extended since many procedures in themselves desirable, but before impossible from the protracted agony they would occasion, became matters of routine practice. Nor have I by any means exhausted the list of the benefits conferred by this discovery.

Anaesthesia in surgery has been from first to last a gift of science. Nitrous oxide, sulphuric ether, and chloroform are all artificial products of chemistry, their employment as anaesthetics was the result of scientific investigation, and their administration, far from being, like the giving of a dose of medicine, a matter of rule of thumb, imperatively demands the vigilant exercise of physiological and pathological knowledge.

While rendering such signal service to surgery, anaesthetics have thrown light upon biology generally. It has been found that they exert their soporific influence not only upon vertebrata, but upon animals so remote in structure from man as bees and other insects. Even the functions of vegetables are suspended by their agency. They thus afford strong confirmation of the great generalization that living matter is of the same essential nature wherever it is met with on this planet, whether in the animal or vegetable kingdom. Anaesthetics have also, in ways to which I need not here refer, powerfully promoted the progress of physiology and pathology.

My next illustration may be taken from the work of Pasteur on fermentation. The prevailing opinion regarding this class of phenomena when they first engaged his attention was that they were occasioned primarily by the oxygen of the

air acting upon unstable animal or vegetable products, which, breaking up under its influence, communicated disturbance to other organic materials in their vicinity, and thus led to their decomposition. Cagniard-Latour had indeed shown several years before that yeast consists essentially of the cells of a microscopic fungus which grows as the sweetwort ferments ; and he had attributed the breaking up of the sugar into alcohol and carbonic acid to the growth of the micro-organism. In Germany, Schwann, who independently discovered the yeast plant, had published very striking experiments in support of analogous ideas regarding the putrefaction of meat. Such views had also found other advocates, but they had become utterly discredited, largely through the great authority of Liebig, who bitterly opposed them.

Pasteur, having been appointed as a young man Dean of the Faculty of Sciences in the University of Lille, a town where the products of alcoholic fermentation were staple articles of manufacture, determined to study that process thoroughly ; and as a result he became firmly convinced of the correctness of Cagniard-Latour's views regarding it. In the case of other fermentations, however, nothing fairly comparable to the formation of yeast had till then been observed. This was now done by Pasteur for that fermentation in which sugar is resolved into lactic acid. This lactic fermentation was at that time brought about by adding some animal substance, such as fibrine, to a solution of sugar, together with chalk that should combine with the acid as it was formed. Pasteur saw, what had never before been noticed, that a fine grey deposit was formed, differing little in appearance from the decomposing fibrine, but steadily increasing as the fermentation proceeded. Struck by the analogy presented by the increasing deposit to the growth of yeast in sweetwort, he examined it with the microscope, and found it to consist of minute particles of uniform size. Pasteur was not a biologist, but although these particles were of extreme minuteness in comparison with the constituents of the yeast plant, he felt convinced that they were of an analogous nature, the cells of a tiny microscopic fungus. This he regarded as the essential ferment, the fibrine or other so-called ferment serving, as he believed, merely the purpose of supplying to the growing plant certain chemical ingredients essential to its nutrition not contained in the sugar. And the correctness of this view he confirmed in a very striking manner, by doing away with the fibrine or other animal material altogether, and substituting for it mineral salts containing the requisite chemical elements. A trace of the grey deposit being applied to a solution of sugar containing these salts in addition to the chalk, a brisker lactic fermentation ensued than could be procured in the ordinary way.

I have referred to this research in some detail because it illustrates

Pasteur's acuteness as an observer and his ingenuity in experiment, as well as his almost intuitive perception of truth.

A series of other beautiful investigations followed, clearly proving that all true fermentations, including putrefaction, are caused by the growth of micro-organisms.

It was natural that Pasteur should desire to know how the microbes which he showed to be the essential causes of the various fermentations took their origin. It was at that period a prevalent notion, even among many eminent naturalists, that such humble and minute beings originated *de novo* in decomposing organic substances; the doctrine of spontaneous generation, which had been chased successively from various positions which it once occupied among creatures visible to the naked eye, having taken its last refuge where the objects of study were of such minuteness that their habits and history were correspondingly difficult to trace. Here again, Pasteur at once saw, as if by instinct, on which side the truth lay; and, perceiving its immense importance, he threw himself with ardour into its demonstration. I may describe briefly one class of experiments which he performed with this object. He charged a series of narrow-necked glass flasks with a decoction of yeast, a liquid peculiarly liable to alteration on exposure to the air. Having boiled the liquid in each flask, to kill any living germs it might contain, he sealed its neck with a blow-pipe during ebullition; after which, the flask being allowed to cool, the steam within it condensed, leaving a vacuum above the liquid. If, then, the neck of the flask were broken in any locality, the air at that particular place would rush in to fill the vacuum, carrying with it any living microbes that might be floating in it. The neck of the flask having been again sealed, any germs so introduced would in due time manifest their presence by developing in the clear liquid. When any of such a series of flasks were opened and resealed in an inhabited room, or under the trees of a forest, multitudes of minute living forms made their appearance in them; but if this was done in a cellar long unused, where the suspended organisms, like other dust, might be expected to have all fallen to the ground, the decoction remained perfectly clear and unaltered. The oxygen and other gaseous constituents of the atmosphere were thus shown to be of themselves incapable of inducing any organic development in yeast-water.

Such is a sample of the many well-devised experiments by which he carried to most minds the conviction that, as he expressed it, *la génération spontanée est une chimère*, and that the humblest and minutest living organisms can only originate by parentage from beings like themselves.

Pasteur pointed out the enormous importance of these humble organisms in the economy of nature. It is by their agency that the dead bodies of plants

and animals are resolved into simpler compounds fitted for assimilation by new living forms. Without their aid the world would be, as Pasteur said, *encombré de cadavres*. They are essential not only to our well-being, but to our very existence. Similar microbes must have discharged the same necessary function of removing refuse and providing food for successive generations of plants and animals during the past periods of the world's history; and it is interesting to think that organisms as simple as can well be conceived to have existed when life first appeared upon our globe have, in all probability, propagated the same lowly but most useful offspring during the ages of geological time.

Pasteur's labours on fermentation have had a very important influence upon surgery. I have been often asked to speak on my share in this matter before a public audience; but I have hitherto refused to do so, partly because the details are so entirely technical, but chiefly because I have felt an invincible repugnance to what might seem to savour of self-advertisement. The latter objection now no longer exists, since advancing years have indicated that it is right for me to leave to younger men the practice of my dearly loved profession. And it will perhaps be expected that, if I can make myself intelligible, I should say something upon the subject on the present occasion.

Nothing was formerly more striking in surgical experience than the difference in the behaviour of injuries according to whether the skin was implicated or not. Thus, if the bones of the leg were broken and the skin remained intact, the surgeon applied the necessary apparatus without any other anxiety than that of maintaining a good position of the fragments, although the internal injury to bones and soft parts might be very severe. If, on the other hand, a wound of the skin was present communicating with the broken bones, although the damage might be in other respects comparatively slight, the compound fracture, as it was termed, was one of the most dangerous accidents that could happen. Mr. Syme, who was, I believe, the safest surgeon of his time, once told me that he was inclined to think that it would be, on the whole, better if all compound fractures of the leg were subjected to amputation, without any attempt to save the limb. What was the cause of this astonishing difference? It was clearly in some way due to the exposure of the injured parts to the external world. One obvious effect of such exposure was indicated by the odour of the discharge, which showed that the blood in the wound had undergone putrefactive change by which the bland nutrient liquid had been converted into highly irritating and poisonous substances. I have seen a man with compound fracture of the leg die within two days of the accident, as plainly poisoned by the products of putrefaction as if he had taken a fatal dose of some potent toxic drug.

An external wound of the soft parts might be healed in one of two ways. If its surfaces were clean cut and could be brought into accurate apposition, it might unite rapidly and painlessly 'by the first intention'. This, however, was exceptional. Too often the surgeon's efforts to obtain primary union were frustrated: the wound inflamed and the retentive stitches had to be removed, allowing it to gape; and then, as if it had been left open from the first, healing had to be effected in the other way, which it is necessary for me briefly to describe. An exposed raw surface became covered in the first instance with a layer of clotted blood or certain of its constituents, which invariably putrefied; and the irritation of the sensitive tissues by the putrid products appeared to me to account sufficiently for the inflammation which always occurred in and around an open wound during the three or four days which elapsed before what were termed 'granulations' had been produced. These constituted a coarsely granular coating of very imperfect or embryonic structure, destitute of sensory nerves and prone to throw off matter or pus, rather than absorb, as freshly divided tissues do, the products of putrefaction. The granulations thus formed a beautiful living plaster, which protected the sensitive parts beneath from irritation, and the system generally from poisoning and consequent febrile disturbance. The granulations had other useful properties, of which I may mention their tendency to shrink as they grew, thus gradually reducing the dimensions of the sore. Meanwhile, another cause of its diminution was in operation. The cells of the epidermis or scarf-skin of the cutaneous margins were perpetually producing a crop of young cells of similar nature, which gradually spread over the granulations till they covered them entirely, and a complete cicatrix or scar was the result. Such was the other mode of healing, that by granulation and cicatrization; a process which, when it proceeded unchecked to its completion, commanded our profound admiration. It was, however, essentially tedious compared with primary union, while, as we have seen, it was always preceded by more or less inflammation and fever, sometimes very serious in their effects. It was also liable to unforeseen interruptions. The sore might become larger instead of smaller, cicatrization giving place to ulceration in one of its various forms, or even to the frightful destruction of tissue which, from the circumstance that it was most frequently met with in hospitals, was termed hospital gangrene. Other serious and often fatal complications might arise, which the surgeon could only regard as untoward accidents, and over which he had no efficient control.

It will be readily understood from the above description that the inflammation which so often frustrated the surgeon's endeavours after primary union was in my opinion essentially due to decomposition of blood within the wound.

These and many other considerations had long impressed me with the greatness of the evil of putrefaction in surgery. I had done my best to mitigate it by scrupulous ordinary cleanliness and the use of various deodorant lotions. But to prevent it altogether appeared hopeless while we believed with Liebig that its primary cause was the atmospheric oxygen which, in accordance with the researches of Graham, could not fail to be perpetually diffused through the porous dressings which were used to absorb the blood discharged from the wound. But when Pasteur had shown that putrefaction was a fermentation caused by the growth of microbes, and that these could not arise *de novo* in the decomposable substance, the problem assumed a more hopeful aspect. If the wound could be treated with some substance which, without doing too serious mischief to the human tissues, would kill the microbes already contained in it and prevent the future access of others in the living state, putrefaction might be prevented, however freely the air with its oxygen might enter. I had heard of carbolic acid as having a remarkable deodorizing effect upon sewage, and having obtained from my colleague, Dr. Anderson, Professor of Chemistry in the University of Glasgow, a sample which he had of this product, then little more than a chemical curiosity in Scotland, I determined to try it in compound fractures. Applying it undiluted to the wound, with an arrangement for its occasional renewal, I had the joy of seeing these formidable injuries follow the same safe and tranquil course as simple fractures, in which the skin remains unbroken.

At the same time we had the intense interest of observing in open wounds what had previously been hidden from human view, the manner in which subcutaneous injuries are repaired. Of special interest was the process by which portions of tissue killed by the violence of the accident were disposed of, as contrasted with what had till then been invariably witnessed. Dead parts had been always seen to be gradually separated from the living by an inflammatory process and thrown off as sloughs. But when protected by the antiseptic dressing from becoming putrid and therefore irritating, a structure deprived of its life caused no disturbance in its vicinity; and, on the contrary, being of a nutritious nature, it served as pabulum for the growing elements of the neighbouring living structures, and these became in due time entirely substituted for it. Even dead bone was seen to be thus replaced by living osseous tissue.

This suggested the idea of using threads of dead animal structures for tying blood-vessels; and this was realized by means of catgut, which is made from the intestine of the sheep. If deprived of living microbes, and otherwise properly prepared, catgut answers its purpose completely; the knot holding

securely, while the ligature around the vessel becomes gradually absorbed and replaced by a ring of living tissue. The threads, instead of being left long as before, could now be cut short, and the tedious process of separation of the ligature, with its attendant serious danger of bleeding, was avoided.

Undiluted carbolic acid is a powerful caustic ; and although it might be employed in compound fracture, where some loss of tissue was of little moment in comparison with the tremendous danger to be averted, it was altogether unsuitable for wounds made by the surgeon. It soon appeared, however, that the acid would answer the purpose aimed at, though used in diluted forms devoid of caustic action, and therefore applicable to operative surgery. According to our then existing knowledge, two essential points had to be aimed at : to conduct the operation so that on its completion the wound should contain no living microbes, and to apply a dressing capable of preventing the access of other living organisms till the time should have arrived for changing it.

Carbolic acid lent itself well to both these objects. Our experience with this agent brought out what was, I believe, a new principle in pharmacology—namely, that the energy of action of any substance upon the human tissues depends not only upon the proportion in which it is contained in the material used as a vehicle for its administration, but also upon the degree of tenacity with which it is held by its solvent. Water dissolves carbolic acid sparingly and holds it extremely lightly, leaving it free to act energetically on other things for which it has greater affinity, while various organic substances absorb it greedily and hold it tenaciously. Hence its watery solution seemed admirably suited for a detergent lotion to be used for destroying any microbes that might fall upon the wound during the operation, and for purifying the surrounding skin and also the surgeon's hands and instruments. For the last-named purpose it had the further advantage that it did not act on steel.

For an external dressing the watery solution was not adapted, as it soon lost the acid it contained, and was irritating while it lasted. For this purpose some organic substances were found to answer well. Large proportions of the acid could be blended with them in so bland a form as to be unirritating ; and such mixtures, while perpetually giving off enough of the volatile salt to prevent organic development in the discharges that flowed past them, served as a reliable store of the antiseptic for days together.

The appliances which I first used for carrying out the antiseptic principle were both rude and needlessly complicated. The years that have since passed have witnessed great improvements in both respects. Of the various materials which have been employed by myself and others, and their modes of application, I need say nothing except to express my belief, as a matter of long experience,

that carbolic acid, by virtue of its powerful affinity for the epidermis and oily matters associated with it, and also its great penetrating power, is still the best agent at our disposal for purifying the skin around the wound. But I must say a few words regarding a most important simplification of our procedure. Pasteur, as we have seen, had shown that the air of every inhabited room teems with microbes ; and for a long time I employed various more or less elaborate precautions against the living atmospheric dust, not doubting that, as all wounds except the few which healed completely by the first intention, underwent putrefactive fermentation, the blood must be a peculiarly favourable soil for the growth of putrefactive microbes. But I afterwards learnt that such was by no means the case. I had performed many experiments in confirmation of Pasteur's germ theory, not indeed in order to satisfy myself of its truth, but in the hope of convincing others. I had observed that uncontaminated milk, which would remain unaltered for an indefinite time if protected from dust, was made to teem with microbes of different kinds by a very brief exposure to the atmosphere, and that the same effect was produced by the addition of a drop of ordinary water. But when I came to experiment with blood drawn with antiseptic precautions into sterilized vessels, I saw to my surprise that it might remain free from microbes in spite of similar access of air or treatment with water. I even found that if very putrid blood was largely diluted with sterilized water, so as to diffuse its microbes widely and wash them of their acrid products, a drop of such dilution added to pure blood might leave it unchanged for days at the temperature of the body, although a trace of the septic liquid undiluted caused intense putrefaction within twenty-four hours. Hence I was led to conclude that it was the grosser forms of septic mischief, rather than microbes in the attenuated condition in which they existed in the atmosphere, that we had to dread in surgical practice. And at the London Medical Congress in 1881, I hinted, when describing the experiments I have alluded to, that it might turn out possible to disregard altogether the atmospheric dust. But greatly as I should have rejoiced at such a simplification of our procedure, if justifiable, I did not then venture to test it in practice. I knew that with the safeguards which we then employed I could ensure the safety of my patients; and I did not dare to imperil it by relaxing them. There is one golden rule for all experiments upon our fellow men. Let the thing tried be that which, according to our best judgement, is the most likely to promote the welfare of the patient. In other words, Do as you would be done by.

Nine years later, however, at the Berlin Congress in 1890, I was able to bring forward what was, I believe, absolute demonstration of the harmlessness of

the atmospheric dust in surgical operations. This conclusion has been justified by subsequent experience: the irritation of the wound by antiseptic irrigation and washing may therefore now be avoided, and Nature left quite undisturbed to carry out her best methods of repair, while the surgeon may conduct his operations as simply as in former days, provided always that deeply impressed with the tremendous importance of his object, and inspiring the same conviction in all his assistants, he vigilantly maintains from first to last, with a care that, once learnt, becomes instinctive, but for the want of which nothing else can compensate, the use of the simple means which will suffice to exclude from the wound the coarser forms of septic impurity.

Even our earlier and ruder methods of carrying out the antiseptic principle soon produced a wonderful change in my surgical wards in the Glasgow Royal Infirmary, which, from being some of the most unhealthy in the kingdom, became, as I believe I may say without exaggeration, the healthiest in the world; while other wards, separated from mine only by a passage a few feet broad, where former modes of treatment were for a while continued, retained their former insalubrity. This result, I need hardly remark, was not in any degree due to special skill on my part, but simply to the strenuous endeavour to carry out strictly what seemed to me a principle of supreme importance.

Equally striking changes were afterwards witnessed in other institutions. Of these I may give one example. In the great Allgemeines Krankenhaus of Munich, hospital gangrene had become more and more rife from year to year, till at length the frightful condition was reached that 80 per cent. of all wounds became affected by it. It is only just to the memory of Professor von Nussbaum, then the head of that establishment, to say that he had done his utmost to check this frightful scourge; and that the evil was not caused by anything peculiar in his management was shown by the fact that in a private hospital under his care there was no unusual unhealthiness. The larger institution seemed to have become hopelessly infected, and the city authorities were contemplating its demolition and reconstruction. Under these circumstances, Professor von Nussbaum dispatched his chief assistant, Dr. Lindpaintner, to Edinburgh, where I at that time occupied the chair of clinical surgery, to learn the details of the antiseptic system as we then practised it. He remained until he had entirely mastered them, and after his return all the cases were on a certain day dressed on our plan. From that day forward not a single case of hospital gangrene occurred in the Krankenhaus. The fearful disease pyaemia likewise disappeared, and erysipelas soon followed its example.

But it was by no means only in removing the unhealthiness of hospitals that the antiseptic system showed its benefits. Inflammation being suppressed,

with attendant pain, fever, and wasting discharge, the sufferings of the patient were, of course, immensely lessened ; rapid primary union being now the rule, convalescence was correspondingly curtailed ; while as regards safety and the essential nature of the mode of repair, it became a matter of indifference whether the wound had clean-cut surfaces which could be closely approximated, or whether the injury inflicted had been such as to cause destruction of tissue. And operations which had been regarded from time immemorial as unjustifiable were adopted with complete safety.

It pleases me to think that there is an ever-increasing number of practitioners throughout the world to whom this will not appear the language of exaggeration. There are cases in which, from the situation of the part concerned or other unusual circumstances, it is impossible to carry out the antiseptic system completely. These, however, are quite exceptional ; and even in them much has been done to mitigate the evil which cannot be altogether avoided.

I ask your indulgence if I have seemed to dwell too long upon matters in which I have been personally concerned. I now gladly return to the labours of others.

The striking results of the application of the germ theory to surgery acted as a powerful stimulus to the investigation of the nature of the micro-organisms concerned ; and it soon appeared that putrefaction was by no means the only evil of microbic origin to which wounds were liable. I had myself very early noticed that hospital gangrene was not necessarily attended by any unpleasant odour ; and I afterwards made a similar observation regarding the matter formed in a remarkable epidemic of erysipelas in Edinburgh obviously of infective character. I had also seen a careless dressing followed by the occurrence of suppuration without putrefaction. And as these non-putrefactive disorders had the same self-propagating property as ferments, and were suppressed by the same antiseptic agencies which were used for combating the putrefactive microbes, I did not doubt that they were of an analogous origin ; and I ventured to express the view that, just as the various fermentations had each its special microbe, so it might be with the various complications of wounds. This surmise was afterwards amply verified. Professor Ogston, of Aberdeen, was an early worker in this field, and showed that in acute abscesses, that is to say those which run a rapid course, the matter, although often quite free from unpleasant odour, invariably contains micro-organisms belonging to the group which, from the spherical form of their elements, are termed micrococci ; and these he classed as streptococci or staphylococci, according as they were arranged in chains or disposed in irregular clusters like bunches of grapes. The German pathologist, Fehleisen, followed with a beautiful research, by which he clearly proved that

erysipelas is caused by a streptococcus. A host of earnest workers in different countries have cultivated the new science of bacteriology, and, while opening up a wide fresh domain of biology, have demonstrated in so many cases the causal relation between special micro-organisms and special diseases, not only in wounds but in the system generally, as to afford ample confirmation of the induction which had been made by Pasteur that all infective disorders are of microbic origin.

Not that we can look forward with anything like confidence to being able ever to see the *materies morbi* of every disease of this nature. One of the latest of such discoveries has been that by Pfeiffer of Berlin of the bacillus of influenza, perhaps the most minute of all micro-organisms ever yet detected. The bacillus of anthrax, the cause of a plague common among cattle in some parts of Europe, and often communicated to sorters of foreign wool in this country, is a giant as compared with this tiny being; and supposing the microbe of any infectious fever to be as much smaller than the influenza bacillus as this is less than that of anthrax, a by no means unlikely hypothesis, it is probable that it would never be visible to man. The improvements of the microscope, based on the principle established by my father in the earlier part of the century, have apparently nearly reached the limits of what is possible. But that such parasites are really the causes of all this great class of diseases can no longer be doubted.

The first rational step towards the prevention or cure of disease is to know its cause; and it is impossible to overestimate the practical value of researches such as those to which I am now referring. Among their many achievements is what may be fairly regarded as the most important discovery ever made in pathology, because it revealed the true nature of the disease which causes more sickness and death in the human race than any other. It was made by Robert Koch, who greatly distinguished himself, when a practitioner in an obscure town in Germany, by the remarkable combination of experimental acuteness and skill, chemical and optical knowledge and successful micro-photography, which he brought to bear upon the elucidation of infective diseases of wounds in the lower animals; in recognition of which service the enlightened Prussian Government at once appointed him to an official position of great importance in Berlin. There he conducted various important researches; and at the London Congress in 1881 he showed to us for the first time the bacillus of tubercle. Wonderful light was thrown by this discovery upon a great group of diseases which had before been rather guessed than known to be of allied nature; a precision and efficacy never before possible was introduced into their surgical treatment, while the physician became guided by new and sure light as regards their diagnosis and prevention.

At that same London Congress Koch demonstrated to us his 'plate culture'

of bacteria, which was so important that I must devote a few words to its description. With a view to the successful study of the habits and effects of any particular microbe outside the living body, it is essential that it should be present unmixed in the medium in which it is cultivated. It can be readily understood how difficult it must have been to isolate any particular micro-organism when it existed mixed, as was often the case, with a multitude of other forms. In fact, the various ingenious attempts made to effect this object had often proved entire failures. Koch, however, by an ingenious procedure converted what had been before impossible into a matter of the utmost facility. In the broth or other nutrient liquid which was to serve as food for the growing microbe he dissolved, by aid of heat, just enough gelatine to ensure that, while it should become a solid mass when cold, it should remain fluid though reduced in temperature so much as to be incapable of killing living germs. To the medium thus partially cooled was added some liquid containing, among others, the microbe to be investigated ; and the mixture was thoroughly shaken so as to diffuse the bacteria and separate them from each other. Some of the liquid was then poured out in a thin layer upon a glass plate and allowed to cool so as to assume the solid form. The various microbes, fixed in the gelatine and so prevented from intermingling, proceeded to develop each its special progeny, which in course of time showed itself as an opaque speck in the transparent film. Any one of such specks could now be removed and transferred to another vessel in which the microbe composing it grew in perfect isolation.

Pasteur was present at this demonstration, and expressed his sense of the great progress effected by the new method. It was soon introduced into his own institute and other laboratories throughout the world ; and it has immensely facilitated bacteriological study.

One fruit of it in Koch's own hands was the discovery of the microbe of cholera in India, whither he went to study the disease. This organism was termed by Koch from its curved form the ' comma bacillus ', and by the French the cholera vibrio. Great doubts were for a long time felt regarding this discovery. Several other kinds of bacteria were found of the same shape, some of them producing very similar appearances in culture media. But bacteriologists are now universally agreed that, although various other conditions are necessary to the production of an attack of cholera besides the mere presence of the vibrio, yet it is the essential *materies morbi* ; and it is by the aid of the diagnosis which its presence in any case of true cholera enables the bacteriologist to make, that threatened invasions of this awful disease have of late years been so successfully repelled from our shores. If bacteriology had done nothing more for us than this, it might well have earned our gratitude.

I have next to invite your attention to some earlier work of Pasteur. There is a disease known in France under the name of *choléra des poules*, which often produced great havoc among the poultry yards of Paris. It had been observed that the blood of birds that had died of this disease was peopled by a multitude of minute bacteria, not very dissimilar in form and size to the microbe of the lactic ferment to which I have before referred. And Pasteur found that, if this bacterium was cultivated outside the body for a protracted period under certain conditions, it underwent a remarkable diminution of its virulence ; so that, if inoculated into a healthy fowl, it no longer caused the death of the bird, as it would have done in its original condition, but produced a milder form of the disease which was not fatal. And this altered character of the microbe, caused by certain conditions, was found to persist in successive generations cultivated in the ordinary way. Thus was discovered the great fact of what Pasteur termed the *atténuation des virus*, which at once gave the clue to understanding what had before been quite mysterious, the difference in virulence of the same disease in different epidemics.

But he made the further very important observation that a bird which had gone through the mild form of the complaint had acquired immunity against it in its most virulent condition. Pasteur afterwards succeeded in obtaining mitigated varieties of microbes for some other diseases ; and he applied with great success the principle which he had discovered in fowl-cholera for protecting the larger domestic animals against the plague of anthrax. The preparations used for such preventive inoculations he termed ' vaccins ' in honour of our great countryman, Edward Jenner. For Pasteur at once saw the analogy between the immunity to fowl-cholera produced by its attenuated virus and the protection afforded against small-pox by vaccination. And while pathologists still hesitated, he had no doubt of the correctness of Jenner's expression *variolae vaccinae*, or small-pox in the cow.

It is just a hundred years since Jenner made the crucial experiment of inoculating with small-pox a boy whom he had previously vaccinated, the result being, as he anticipated, that the boy was quite unaffected. It may be remarked that this was a perfectly legitimate experiment, involving no danger to the subject of it. Inoculation was at that time the established practice ; and if vaccination should prove nugatory, the inoculation would be only what would have been otherwise called for ; while it would be perfectly harmless if the hoped-for effect of vaccination had been produced.

We are a practical people, not much addicted to personal commemorations, although our nation did indeed celebrate with fitting splendour the jubilee of the reign of our beloved Queen ; and at the invitation of Glasgow the scientific

world has lately marked in a manner, though different, as imposing, the jubilee of the life-work of a sovereign in science (Lord Kelvin). But while we cannot be astonished that the centenary of Jenner's immortal discovery should have failed to receive general recognition in this country, it is melancholy to think that this year should, in his native county, have been distinguished by a terrible illustration of the results which would sooner or later inevitably follow the general neglect of his prescriptions.

I have no desire to speak severely of the Gloucester Guardians. They are not sanitary authorities, and had not the technical knowledge necessary to enable them to judge between the teachings of true science and the declamations of misguided, though well-meaning, enthusiasts. They did what they believed to be right ; and when roused to a sense of the greatness of their mistake, they did their very best to repair it, so that their city is said to be now the best vaccinated in Her Majesty's dominions. But though by their praiseworthy exertions they succeeded in promptly checking the raging epidemic, they cannot recall the dead to life, or restore beauty to marred features, or sight to blinded eyes. Would that the entire country and our Legislature might take duly to heart this object-lesson!

How completely the medical profession were convinced of the efficacy of vaccination in the early part of this century was strikingly illustrated by an account given by Professor Crookshank, in his interesting history of this subject, of several eminent medical men in Edinburgh meeting to see the, to them, unprecedented fact of a vaccinated person having taken small-pox. It has, of course, since become well known that the milder form of the disease, as modified by passing through the cow, confers a less permanent protection than the original human disorder. This it was, of course, impossible for Jenner to foresee. It is, indeed, a question of degree, since a second attack of ordinary small-pox is occasionally known to occur, and vaccination, long after it has ceased to give perfect immunity, greatly modifies the character of the disorder and diminishes its danger. And, happily, in revaccination after a certain number of years we have the means of making Jenner's work complete. I understand that the majority of the Commissioners, who have recently issued their report upon this subject, while recognising the value and importance of revaccination, are so impressed with the difficulties that would attend making it compulsory by legislation that they do not recommend that course ; although it is advocated by two of their number who are of peculiarly high authority on such a question. I was lately told by a Berlin professor that no serious difficulty is experienced in carrying out the compulsory law that prevails in Germany. The masters of the schools are directed to ascertain in the case of every child attaining the age of twelve whether revaccination has been practised. If not, and the parents refuse to

have it done, they are fined one mark. If this does not prove effectual, the fine is doubled : and if even the double penalty should not prove efficacious, a second doubling of it would follow, but, as my informant remarked, it is very seldom that it is called for. The result is that small-pox is a matter of extreme rarity in that country ; while it is almost unknown in the huge German army, in consequence of the rule that every soldier is revaccinated on entering the service. Whatever view our Legislature may take on this question, one thing seems to me clear : that it will be the duty of Government to encourage by every available means the use of calf lymph, so as to exclude the possibility of the communication of any human disease to the child, and to institute such efficient inspection of vaccination institutes as shall ensure careful antiseptic arrangements, and so prevent contamination by extraneous microbes. If this were done, 'conscientious objections' would cease to have any rational basis. At the same time, the administration of the regulations on vaccination should be transferred (as advised by the Commissioners) to competent sanitary authorities.

But to return to Pasteur. In 1880 he entered upon the study of that terrible but then most obscure disease, hydrophobia or rabies, which from its infective character he was sure must be of microbic origin, although no micro-organism could be detected in it. He early demonstrated the new pathological fact that the virus had its essential seat in the nervous system. This proved the key to his success in this subject. One result that flowed from it has been the cause of unspeakable consolation to many. The foolish practice is still too prevalent of killing the dog that has bitten any one, on the absurd notion that, if it were mad, its destruction would prevent the occurrence of hydrophobia in the person bitten. The idea of the bare possibility of the animal having been so affected causes an agony of suspense during the long weeks or months of possible incubation of the disease. Very serious nervous symptoms aping true hydrophobia have been known to result from the terror thus inspired. Pasteur showed that if a little of the brain or spinal cord of a dog that had been really mad was inoculated in an appropriate manner into a rabbit, it infallibly caused rabies in that animal in a few days. If, therefore, such an experiment was made with a negative result, the conclusion might be drawn with certainty that the dog had been healthy. It is perhaps right that I should say that the inoculation is painlessly done under an anaesthetic, and that in the rabbit rabies does not assume the violent form that it does in the dog, but produces gradual loss of power with little if any suffering.

This is the more satisfactory because rabbits in which the disease has been thus artificially induced are employed in carrying out what was Pasteur's greatest triumph, the preventive treatment of hydrophobia in the human subject. We

have seen that Pasteur discovered that microbes might under some circumstances undergo mitigation of their virulence. He afterwards found that under different conditions they might have it exalted, or, as he expressed it, there might be a *renforcement du virus*. Such proved to be the case with rabies in the rabbit; so that the spinal cords of animals which had died of it contained the poison in a highly intensified condition. But he also found that if such a highly virulent cord was suspended under strict antiseptic precautions in a dry atmosphere at a certain temperature, it gradually from day to day lost in potency, till in course of time it became absolutely inert. If now an emulsion of such a harmless cord was introduced under the skin of an animal, as in the subcutaneous administration of morphia, it might be followed without harm another day by a similar dose of a cord still rather poisonous; and so from day to day stronger and stronger injections might be used, the system becoming gradually accustomed to the poison, till a degree of virulence had been reached far exceeding that of the bite of a mad dog. When this had been attained, the animal proved incapable of taking the disease in the ordinary way; and more than that, if such treatment was adopted after an animal had already received the poison, provided that too long a time had not elapsed, the outbreak of the disease was prevented. It was only after great searching of heart that Pasteur, after consultation with some trusted medical friends, ventured upon trying this practice upon man. It has since been extensively adopted in various parts of the world with increasing success as the details of the method were improved. It is not of course the case that every one bitten by a really rabid animal takes the disease; but the percentage of those who do so, which was formerly large, has been reduced almost to zero by this treatment, if not too long delayed.

While the intensity of rabies in the rabbit is undoubtedly due to a peculiarly virulent form of the microbe concerned, we cannot suppose that the daily diminishing potency of the cord suspended in dry warm air is an instance of attenuation of virus, using the term ‘ virus ’ as synonymous with the microbe concerned. In other words, we have no reason to believe that the special micro-organism of hydrophobia continues to develop in the dead cord and produce successively a milder and milder progeny; since rabies cannot be cultivated in the nervous system of a dead animal. We must rather conclude that there must be some chemical poison present which gradually loses its potency as time passes. And this leads me to refer to another most important branch of this large subject of bacteriology, that of the poisonous products of microbes.

It was shown several years ago by Roux and Yersin, working in the *Institut Pasteur*, that the crust or false membrane which forms upon the throats of patients affected with diphtheria contains bacteria which can be cultivated outside

the body in a nutrient liquid, with the result that it acquires poisonous qualities of astonishing intensity, comparable to that of the secretion of the poison-glands of the most venomous serpents. And they also ascertained that the liquid retained this property after the microbes had been removed from it by filtration, which proved that the poison must be a chemical substance in solution, as distinguished from the living element which had produced it. These poisonous products of bacteria, or toxins as they have been termed, explain the deadly effects of some microbes, which it would otherwise be impossible to understand. Thus, in diphtheria itself, the special bacillus which was shown by Löffler to be its cause does not become propagated in the blood, like the microbe of chicken cholera, but remains confined to the surface on which it first appeared ; but the toxin which it secretes is absorbed from that surface into the blood, and so poisons the system. Similar observations have been made with regard to the microbes of some other diseases, as, for example, the bacillus of tetanus or lock-jaw. This remains localized in the wound, but forms a special toxin of extreme potency, which becomes absorbed and diffused through the body.

Wonderful as it seems, each poisonous microbe appears to form its own peculiar toxin. Koch's tuberculin was of this nature ; a product of the growth of the tubercle bacillus in culture media. Here, again, great effects were produced by extremely minute quantities of the substance ; but here a new peculiarity showed itself, viz. that patients affected with tubercular disease, in any of its varied forms, exhibited inflammation in the affected part and general fever after receiving under the skin an amount of the material which had no effect whatever upon healthy persons. I witnessed in Berlin some instance of these effects, which were simply astounding. Patients affected with a peculiar form of obstinate ulcer of the face showed, after a single injection of the tuberculin, violent inflammatory redness and swelling of the sore and surrounding skin ; and, what was equally surprising, when this disturbance subsided the disease was found to have undergone great improvement. By repetitions of such procedures, ulcers which had previously been steadily advancing, in spite of ordinary treatment, became greatly reduced in size, and in some instances apparently cured. Such results led Koch to believe that he had obtained an effectual means of dealing with tubercular disease in all its forms. Unhappily, the apparent cure proved to be only of transient duration, and the high hopes which had been inspired by Koch's great reputation were dashed. It is but fair to say that he was strongly urged to publish before he was himself disposed to do so, and we cannot but regret that he yielded to the pressure put upon him.

But though Koch's sanguine anticipations were not realized, it would be a great mistake to suppose that his labours with tuberculin have been fruitless.

Cattle are liable to tubercle, and, when affected with it, may become a very serious source of infection for human beings, more especially when the disease affects the udders of cows, and so contaminates the milk. By virtue of the close affinity that prevails between the lower animals and ourselves, in disease as well as in health, tuberculin produces fever in tubercular cows in doses which do not affect healthy beasts. Thus, by the subcutaneous use of a little of the fluid, tubercle latent in internal organs of an apparently healthy cow can be with certainty revealed, and the slaughter of the animal after this discovery protects man from infection.

It has been ascertained that glanders presents a precise analogy with tubercle as regards the effects of its toxic products. If the microbe which has been found to be the cause of this disease is cultivated in appropriate media, it produces a poison which has received the name of mallein, and the subcutaneous injection of a suitable dose of this fluid into a glandered horse causes striking febrile symptoms which do not occur in a healthy animal. Glanders, like tubercle, may exist in insidious latent forms which there was formerly no possibility of detecting, but which are at once disclosed by this means. If a glandered horse has been accidentally introduced into a large stable, this method of diagnosis surely tells if it has infected others. All receive a little mallein. Those which become affected with fever are slaughtered, and thus not only is the disease prevented from spreading to other horses, but the grooms are protected from a mortal disorder.

This valuable resource sprang from Koch's work on tuberculin, which has also indirectly done good in other ways. His distinguished pupil, Behring, has expressly attributed to those researches the inspiration of the work which led him and his since famous collaborateur, the Japanese Kitasato, to their surprising discovery of antitoxic serum. They found that if an animal of a species liable to diphtheria or tetanus received a quantity of the respective toxin, so small as to be harmless, and afterwards, at suitable intervals, successively stronger and stronger doses, the creature, in course of time, acquired such a tolerance for the poison as to be able to receive with impunity a quantity very much greater than would at the outset have proved fatal. So far, we have nothing more than seems to correspond with the effects of the increasingly potent cords in Pasteur's treatment of rabies. But what was entirely new in their results was that, if blood was drawn from an animal which had acquired this high degree of artificial immunity, and some of the clear fluid or serum which exuded from it after it had clotted was introduced under the skin of another animal, this second animal acquired a strong, though more transient, immunity against the particular toxin concerned. The serum in some way counteracted the toxin or was antitoxic. But, more than that, if some of the antitoxic serum was applied to an

animal after it had already received a poisonous dose of the toxin, it preserved the life of the creature, provided that too long a time had not elapsed after the poison was introduced. In other words, the antitoxin proved to be not only preventive but curative.

Similar results were afterwards obtained by Ehrlich, of Berlin, with some poisons not of bacterial origin, but derived from the vegetable kingdom; and quite recently the independent labours of Calmette of Lille, and Fraser of Edinburgh, have shown that antidotes of wonderful efficacy against the venom of serpents may be procured on the same principle. Calmette has obtained antitoxin so powerful that a quantity of it only a 200,000th part of the weight of an animal will protect it perfectly against a dose of the secretion of the poison-glands of the most venomous serpents known to exist, which without such protection would have proved fatal in four hours. For curative purposes larger quantities of the remedy are required, but cases have been already published by Calmette in which death appears to have been averted in the human subject by this treatment.

Behring's darling object was to discover means of curing tetanus and diphtheria in man. In tetanus the conditions are not favourable; because the specific bacilli lurk in the depths of the wound, and only declare their presence by symptoms caused by their toxin having been already in a greater or less amount diffused through the system; and in every case of this disease there must be a fear that the antidote may be applied too late to be useful. But in diphtheria the bacilli very early manifest their presence by the false membrane which they cause upon the throat, so that the antitoxin has a fair chance; and here we are justified in saying that Behring's object has been attained.

The problem, however, was by no means so simple as in the case of some mere chemical poison. However effectual the antitoxin might be against the toxin, if it left the bacilli intact, not only would repeated injections be required to maintain the transient immunity to the poison perpetually secreted by the microbes, but the bacilli might by their growth and extension cause obstruction of the respiratory passages.

Roux, however, whose name must always be mentioned with honour in relation to this subject, effectually disposed of this difficulty. He showed by experiments on animals that a diphtheritic false membrane, rapidly extending and accompanied by surrounding inflammation, was brought to a stand by the use of the antitoxin, and soon dropped off, leaving a healthy surface. Whatever be the explanation, the fact was thus established that the antitoxic serum, while it renders the toxin harmless, causes the microbe to languish and disappear.

No theoretical objection could now be urged against the treatment; and it has during the last two years been extensively tested in practice in various parts

of the world, and it has gradually made its way more and more into the confidence of the profession. One important piece of evidence in its favour in this country is derived from the report of the six large hospitals under the management of the London Asylums Board. The medical officers of these hospitals at first naturally regarded the practice with scepticism : but as it appeared to be at least harmless, they gave it a trial ; and during the year 1895 it was very generally employed upon the 2,182 cases admitted ; and they have all become convinced of its great value. In the nature of things, if the theory of the treatment is correct, the best results must be obtained when the patients are admitted at an early stage of the attack, before there has been time for much poisoning of the system ; and accordingly we learn from the report that, comparing 1895 with 1894, during which latter year the ordinary treatment had been used, the percentage of mortality, in all the six hospitals combined, among the patients admitted on the first day of the disease, which in 1894 was 22·5, was only 4·6 in 1895 ; and for those admitted on the second day the numbers are 27 for 1894 and 14·8 for 1895. Thus for cases admitted on the first day the mortality was only one-fifth of what it was in the previous year, and for those entering on the second it was halved. Unfortunately in the low parts of London which furnish most of these patients the parents too often delay sending in the children till much later ; so that on the average no less than 67·5 per cent. were admitted on the fourth day of the disease or later. Hence the aggregate statistics of all cases are not nearly so striking. Nevertheless, taking it altogether, the mortality in 1895 was less than had ever before been experienced in those hospitals. I should add that there was no reason to think that the disease was of a milder type than usual in 1895 ; and no change whatever was made in the treatment except as regards the antitoxic injections.

There is one piece of evidence recorded in the report which, though it is not concerned with high numbers, is well worthy of notice. It relates to a special institution to which convalescents from scarlet fever are sent from all the six hospitals. Such patients occasionally contract diphtheria, and when they do so the added disease has generally proved extremely fatal. In the five years preceding the introduction of the treatment with antitoxin the mortality from this cause had never been less than 50 per cent., and averaged on the whole 61·9 per cent. During 1895, under antitoxin, the deaths among the 119 patients of this class were only 7·5 per cent., or one-eighth of what had been previously experienced. This very striking result seems to be naturally explained by the fact that these patients being already in hospital when the diphtheria appeared, an unusually early opportunity was afforded for dealing with it.

There are certain cases of so malignant a character from the first that no

treatment will probably ever be able to cope with them. But taking all cases together, it seems probable that Behring's hope that the mortality may be reduced to 5 per cent. will be fully realized when the public become alive to the paramount importance of having the treatment commenced at the outset of the disease.

There are many able workers in the field of bacteriology whose names time does not permit me to mention, and to whose important labours I cannot refer ; and even those researches of which I have spoken have been, of course, most inadequately dealt with. I feel this especially with regard to Pasteur, whose work shines out more brightly the more his writings are perused.

I have lastly to bring before you a subject which, though not bacteriological, has intimate relations with bacteria. If a drop of blood is drawn from the finger by a prick with a needle and examined microscopically between two plates of glass, there are seen in it minute solid elements of two kinds, the one pale orange bi-concave discs, which, seen in mass, give the red colour to the vital fluid, the other more or less granular spherical masses of the soft material called protoplasm, destitute of colour, and therefore called the colourless or white corpuscles. It has been long known that if the microscope was placed at such a distance from a fire as to have the temperature of the human body, the white corpuscles might be seen to put out and retract little processes or pseudopodia, and by their means crawl over the surface of the glass, just like the extremely low forms of animal life termed, from this faculty of changing their form, amoebae. It was a somewhat weird spectacle, that of seeing what had just before been coursing through our veins moving about like independent creatures. Yet there was nothing in this inconsistent with what we knew of the fixed components of the animal frame. For example, the surface of a frog's tongue is covered with a layer of cells, each of which is provided with two or more lashing filaments or cilia, and those of all the cells acting in concert cause a constant flow of fluid in a definite direction over the organ. If we gently scrape the surface of the animal's tongue, we can detach some of these ciliated cells ; and on examining them with the microscope in a drop of water, we find that they will continue for an indefinite time their lashing movements, which are just as much living or vital in their character as the writhings of a worm. And, as I observed many years ago, these detached cells behave under the influence of a stimulus just like parts connected with the body, the movements of the cilia being excited to greater activity by gentle stimulation, and thrown into a state of temporary inactivity when the irritation was more severe. Thus each constituent element of our bodies may be regarded as in one sense an independent living being, though all work together in marvellous harmony for the good of the body politic. The independent move-

ments of the white corpuscles outside the body were therefore not astonishing; but they long remained matters of mere curiosity. Much interest was called to them by the observation of the German pathologist Cohnheim, that in some inflammatory conditions they passed through the pores in the walls of the finest blood-vessels, and thus escaped into the interstices of the surrounding tissues. Cohnheim attributed their transit to the pressure of the blood. But why it was that, though larger than the red corpuscles, and containing a nucleus which the red ones have not, they alone passed through the pores of the vessels, or why it was that this emigration of the white corpuscles occurred abundantly in some inflammations and was absent in others, was quite unexplained.

These white corpuscles, however, have been invested with extraordinary new interest by the researches of the Russian naturalist and pathologist, Metchnikoff. He observed that, after passing through the walls of the vessels, they not only crawl about like amoebae, but, like them, receive nutritious materials into their soft bodies and digest them. It is thus that the effete materials of a tadpole's tail are got rid of; so that they play a most important part in the function of absorption.

But still more interesting observations followed. He found that a microscopic crustacean, a kind of water-flea, was liable to be infested by a fungus which had exceedingly sharp-pointed spores. These were apt to penetrate the coats of the creature's intestine, and project into its body-cavity. No sooner did this occur with any spore than it became surrounded by a group of the cells which are contained in the cavity of the body and correspond to the white corpuscles of our blood. These proceeded to attempt to devour the spore; and if they succeeded, in every such case the animal was saved from the invasion of the parasite. But if the spores were more than could be disposed of by the devouring cells (phagocytes, as Metchnikoff termed them), the water-flea succumbed.

Starting from this fundamental observation, he ascertained that the microbes of infective diseases are subject to this same process of devouring and digestion, carried on both by the white corpuscles and by cells that line the blood-vessels. And by a long series of most beautiful researches he has, as it appears to me, firmly established the great truth that phagocytosis is the main defensive means possessed by the living body against the invasions of its microscopic foes. The power of the system to produce antitoxic substances to counteract the poisons of microbes is undoubtedly in its own place of great importance. But in the large class of cases in which animals are naturally refractory to particular infective diseases the blood is not found to yield any antitoxic element by which the natural immunity can be accounted for. Here phagocytosis seems to be the sole defensive agency. And even in cases in which the serum does possess antitoxic, or, as it would seem in some cases, germicidal properties, the bodies of the dead

microbes must at last be got rid of by phagocytosis, and some recent observations would seem to indicate that the useful elements of the serum may be, in part at least, derived from the digestive juices of the phagocytes. If ever there was a romantic chapter in pathology, it has surely been that of the story of phagocytosis.

I was myself peculiarly interested by these observations of Metchnikoff's, because they seemed to me to afford clear explanation of the healing of wounds by first intention under circumstances before incomprehensible. Complete primary union was sometimes seen to take place in wounds treated with water dressing, that is to say, a piece of wet lint covered with a layer of oiled silk to keep it moist. This, though cleanly when applied, was invariably putrid within twenty-four hours. The layer of blood between the cut surfaces was thus exposed at the outlet of the wound to a most potent septic focus. How was it prevented from putrefying, as it would have done under such influence if, instead of being between divided living tissues, it had been between plates of glass or other indifferent material? Pasteur's observations pushed the question a step further. It now was, How were the bacteria of putrefaction kept from propagating in the decomposable film? Metchnikoff's phagocytosis supplied the answer. The blood between the lips of the wound became rapidly peopled with phagocytes, which kept guard against the putrefactive microbes and seized them as they endeavoured to enter.

If phagocytosis was ever able to cope with septic microbes in so concentrated and intense a form, it could hardly fail to deal effectually with them in the very mitigated condition in which they are present in the air. We are thus strongly confirmed in our conclusion that the atmospheric dust may safely be disregarded in our operations; and Metchnikoff's researches, while they have illumined the whole pathology of infective diseases, have beautifully completed the theory of antiseptic treatment in surgery.

I might have taken equally striking illustrations of my theme from other departments in which microbes play no part. In fact any attempt to speak of all that the art of healing has borrowed from science and contributed to it during the past half-century would involve a very extensive dissertation on pathology and therapeutics. I have culled specimens from a wide field; and I only hope that in bringing them before you I have not overstepped the bounds of what is fitting before a mixed company. For many of you my remarks can have had little if any novelty: for others they may perhaps possess some interest as showing that Medicine is no unworthy ally of the British Association—that, while her practice is ever more and more based on science, the ceaseless efforts of her votaries to improve what have been fittingly designated *Quae prosunt omnibus artes*, are ever adding largely to the sum of abstract knowledge.

THE THIRD HUXLEY LECTURE[1]

Delivered before the Medical School of Charing Cross Hospital, on October 2, 1900.

WHEN the Council of Charing Cross Hospital did me the great honour of asking me to deliver the third of the lectures instituted by them in memory of Huxley, the illustrious former pupil of their school, at the same time conveying their desire that the subject of it should be my own work, I at first reluctantly declined, on the ground that what I had done had been for the most part already published. But when the Dean, who assured me that he expressed the unanimous wish of his colleagues, urged me to reconsider my decision, I felt unable to refuse compliance with a request so very kindly made. It also occurred to me that, as my papers are scattered through a variety of media of publication, extending over a pretty long period, the earlier ones especially being probably little known to the present generation, it might perhaps be not without interest for me to refer on this occasion to some of the more salient of such observations as bear more or less directly upon the antiseptic system of surgery, while I should at the same time be complying with a wish that has been expressed that I should give some indication of the circumstances that led me to that subject.

As a student at University College I was greatly attracted by Dr. Sharpey's lectures, which inspired me with a love of physiology that has never left me. My father, whose labours (vide 'On the Improvement of Achromatic Compound Microscopes', by J. J. Lister, Esq., *Phil. Trans.*, 1830) had raised the compound microscope from little better than a scientific toy to the powerful engine for investigation which it then already was, had equipped me with a first-rate instrument of that kind, and I employed it with keen interest in verifying the details of histology brought before us by our great master. When I afterwards became house surgeon under Mr. Erichsen, I applied the same means of observation to pathological objects.

One of the earliest records that I find of such work is in the form of sketches of the corpuscles in the pus in a case of pyaemia, which occurred after excision of the elbow in a little boy. The cancellated tissue of the humerus at the seat of operation and the adjacent part of the medullary cavity were seen, on post mortem examination, to be occupied by thick, yellow pus, and similar fluid distended the brachial and axillary veins and their branches,

[1] This lecture was published in the *British Medical Journal* of October 6, 1900. It was reprinted with corrections, in a volume published in February 1907.

including not only those leading from the bone towards the venous trunks, but also those proceeding from other parts of the limb, while the upper part of the axillary was plugged with a firm adhering clot. There was also suppuration in one knee-joint and multiple abscesses in the lungs. I was struck with the fact that the pus was to be found not only in the course of the channels leading from the original seat of mischief to the main trunk, but also in branches along which it must have advanced in the reverse direction in spite of the valves of the veins. The plugging of the axillary seemed also a very noteworthy circumstance. Sédillot had shown that multiple abscesses in the lungs were caused by introducing pus into the veins of an animal; and it seemed probable that the collections of pus in those organs in the present case had been of similar metastatic origin. Yet the plugging of the axillary, shutting off the pus in the veins from the general circulation, seemed inconsistent with such a view. I took careful camera-lucida sketches of the constituents of the pus from the various situations in which it occurred; and I also made a record of the magnifying power employed, by sketching with the camera the scale of a micrometer placed upon the stage of the microscope. And I would venture to recommend this practice strongly to pathologists. The sketch which I then made is as valuable to me to-day as if it had been made yesterday. I see from my drawing what I noted at the time, that the solid constituents of the pus were in no case pus corpuscles such as we then knew them, and I also see that they were not leucocytes. I could not explain at the time the facts that I observed, but subsequent investigation has, I believe, made them intelligible.

An epidemic, as we termed it, of hospital gangrene occurred during my house-surgeoncy, and I was charged with carrying out the treatment. This consisted in scraping away very thoroughly under chloroform the brown pultaceous slough and freely applying acid pernitrate of mercury to the exposed surface. The result was, as a rule, that, when the eschar caused by the powerful caustic separated under poulticing, a perfectly healthy granulating sore was disclosed which healed kindly under ordinary dressings. The only exception to this rule was in the case of a very stout woman, in whom the disease attacked an enormous wound of the forearm caused by an accident which had raised a very large flap of skin. In that case the caustic application removed indeed the pain and the extensive inflammatory blush; but when the slough separated, a small brown spot was seen at one place among the otherwise healthy granulations, and this spread with astonishing rapidity over the entire sore. The treatment was tried again and again with the same result, till, the deep structures of the limb having become seriously involved, Mr. Erichsen

resolved to amputate. On the evening before the day for the operation I again put the patient under chloroform, and, after scraping the sore very thoroughly, allowed the liquid caustic to lie in pools upon it for a quarter of an hour in order to destroy as effectually as possible all material in the sore which might otherwise infect the amputation wound. With a similar object I washed the skin of the limb thoroughly with soap and water, including the shoulder, where it had been decided to perform the amputation. The limb having been removed next day, the stump healed perfectly kindly. Here, as in the other cases, local treatment proved efficacious.

I was greatly struck with the clear evidence which these cases seemed to afford that the disease was of the nature of a purely local poison. In the hope of discovering its nature I examined microscopically the slough from one of the sores, and I made a sketch of some bodies of pretty uniform size which I imagined might be the *materies morbi* in the shape of some kind of fungus. Thus as regards that form of hospital disease, the idea that it was probably of parasitic nature was at that early period already present to my mind.

On visiting Edinburgh by Dr. Sharpey's advice in order to see something of Mr. Syme's practice, I was fascinated by the prominence that he gave to the pathological side of surgery as well as by his rare diagnostic judgement and his surpassing powers as an operator. Under him I had the unexpected great privilege of a second house-surgeoncy, which extended over upwards of a year, and in the great Royal Infirmary I had ample opportunity for observing the behaviour of wounds under the most varied conditions. I was charmed with the superiority of the treatment of recent wounds which I witnessed there over the 'water dressing' which was used at University College after the precepts of Liston, who introduced it in place of what he termed 'filthy unguents'. Water dressing, though cleanly when applied, was invariably putrid within twenty-four hours, and had to be changed daily. Mr. Syme placed pads of dry lint upon the bodies of the flaps, leaving the lips of the wound free for the escape of blood and serum, covering all with a single layer of dry lint and a retaining bandage which gently pressed the cut surfaces together. This dressing was left untouched for four days, during which union by the first intention proceeded undisturbed except in the track of the ligatures upon the blood-vessels, while the discharge found on changing the dressing was scanty and not specially offensive.

But highly successful as this practice was, it could not be continued in the further progress of the case. The ligatures were separated by a process of suppuration, which, even when the tissues had been healthy at the time of operation, became fully established in four days at the latest. The ligatures,

on the other hand, were not fully detached till a later and variable period ; and so long as they remained they perpetuated the formation of pus in the depths of the wound, the retention of which by a dry dressing long continued would have involved disastrous consequences.

Thus, under the best possible management which the knowledge of those days permitted, suppuration was an inevitable attendant on nearly every wound ; and so long as it continued there was no security against the advent of one of the various specially unhealthy conditions, then quite inexplicable, which might ruin the results of the most beautifully planned and executed operations.

The very liberal regulations of the University and College of Surgeons of Edinburgh enabled me, on the expiry of my house-surgeoncy at the infirmary, to start a course of lectures on surgery, qualifying for the examinations of both bodies. The first subject with which I should have to deal was inflammation. The stasis of the blood in the capillaries, as the result of irritating applications, had been long studied in the transparent web of the frog's foot ; and Paget had described similar phenomena in the wing of the mammalian bat. The latest contribution to the subject had been made by Wharton Jones, one of my former teachers at University College, who had received the Astley Cooper Prize for an essay in which observations were recorded leading him to the conclusion that the cause of the arrest of the red corpuscles in the capillaries of an inflamed part was contraction of the arterioles. According to this view, which he supported by very neatly executed experiments, the narrowing of the tubes of supply caused sluggishness of flow in the fields of capillaries supplied by them, and this permitted the red discs to aggregate and so obstruct the channels.

There could be no more doubt of the trustworthiness of Wharton Jones's observations than of the beauty of the drawings with which he illustrated them. But their relation to inflammatory stasis was not so clear ; and I sought further light upon the subject by investigations of my own. My first attempt in this way may be described somewhat in detail. It occurred to me that it would be interesting, instead of the powerful irritants which had been usually applied in such investigations, to try warm water, the mildest of all stimulants to the human body. Having fixed a young frog upon a plate of glass on the stage of a microscope tilted at an angle of about 45°, one of the webs being extended in the field of view, I watched the effect of throwing a few drops of warm water upon the web by means of a syringe. The application of the water was little more than momentary ; and as it flowed off immediately from the sloping surface, I could at once observe the result. This filled me with astonishment, and at first I could not understand what I saw. All appearance of blood-

vessels—arteries, capillaries, and veins—had disappeared; the field being absolutely exsanguine. In a short time the circulation was resumed with greater freedom than ever; and on repeating the experiment I found that the first effect of the stimulus was a state of extreme constriction of the arterioles, which kept back the blood-corpuscles but allowed the liquor sanguinis to pass; so that the capillaries and veins, though retaining their former dimensions, were occupied only by the filtered plasma, itself invisible, while their walls were with difficulty discernible under the low magnifying power that I was using.

Thus was swept away at one stroke the latest theory upon the subject. The condition of contraction of the arterioles, which Wharton Jones had supposed to be the cause of the accumulation of the red corpuscles in the capillaries, had been present in the most perfect conceivable form; but the result had been the very opposite condition.

The explanation of Wharton Jones's mistake became apparent as I proceeded along the path which opened with so much promise. He had never experimented in a perfectly healthy state of the circulation, but had described with great accuracy what could occur only under morbid conditions. For I afterwards learned that the normal temperature of man is deadly to the cold-blooded frog. That animal, which under ordinary conditions exhibits very remarkable persistence of vitality even after somatic death, is killed by being held for about a quarter of an hour in the hand; and if one of its hind feet be similarly warmed, the blood-corpuscles will be found packed and stagnant in the vessels of the webs, as if mustard or any other powerful irritant had been applied to them.

If, on the other hand, in securing the frog for observation under the microscope, scrupulous care was taken to avoid needless exposure of the foot to the warmth of the hands, the threads for fixing the toes being tied by means of long forceps, and each half of the knot done separately, with a fair interval between them, a state of the circulation was seen which is, I believe, even to this day rarely witnessed. The white corpuscles, instead of trailing, more or less sluggishly, along the walls of the venous radicles—the normal condition, according to some modern textbooks—move freely along among the red discs, and these being diffused through a due proportion of liquor sanguinis, the vessels present a pallor which would surprise any one who had seen only the ordinary demonstrations of the circulation, but which might have been anticipated from the appearance, when in health, of the highly vascular sclerotic with its investing conjunctiva, 'the white of the eye'.

Such a method of arranging the foot could not be carried out if the animal

were able to struggle ; but this was effectually prevented in the following way : The frog, wrapped in cold, wet lint, is held in the left hand, and the head, left exposed for the purpose, is depressed with the forefinger so as to stretch the ligament between the occiput and the first vertebra. The junction between the brain and spinal cord is then divided with a tenotome, after which the creature remains perfectly passive as long as may be desired. Comparatively dull though we know sensibility to be in an animal so low in the scale as the frog, it is a comfort to feel that this method must be attended with exceedingly little pain. That caused by the division of the cord is probably almost as momentary as the stroke of the tenotome ; and sensibility as well as motion being abolished in the limbs, the creature cannot feel the tying of the naturally sensitive toes or the subsequent dragging upon them.

This arrangement had the further great advantage of allowing an irritant, even in the form of a drop of liquid, to remain undisturbed at the particular spot to which it was applied, instead of being diffused over the whole web by the movements of the limb. Under these circumstances the highly interesting fact was disclosed that, while the web generally was affected through the nervous system with active congestion, that is to say, with arterial dilatation and consequent very free flow of blood, the characteristic stasis was limited to the area on which the irritant acted directly. In spite of the widening of the tubes of supply, the blood-corpuscles tended to lag more and more behind the liquor sanguinis, till at length complete stagnation occurred. The obstacle to the onward movement of the red discs seemed to be caused by adhesiveness on their part. On careful examination, individual discs were sometimes seen attached to the walls of the vessels. The white corpuscles also showed a tendency to adhere to each other and to the vascular parietes ; and this was seen in all degrees, from the disposition to trail along the venous radicles, before referred to as occurring under slight irritation, to piling up of colourless granular masses of leucocytes large enough to block a venous radicle.[1]

These appearances of the blood-corpuscles in the irritated area were such as were seen in blood examined outside the body between two plates of glass. I had observed similar granular masses of white corpuscles in blood from my own finger, as well as individual leucocytes adhering to the surface of the glass, along which, as has been since observed, they crawl by amoeboid movements.

In the red corpuscles the tendency to mutual adhesion shows itself in

[1] The accumulation of the white corpuscles in the vessels of an inflamed frog's web was described in 1841 by Dr. William Addison and Dr. C. J. B. Williams independently in the *Medical Gazette* of that year.

different forms according to the species of the animal or its state of health. In the frog the prominence of the nuclei leads to very irregular grouping of the oval cells. In man the biconcave circular discs adhere under normal circumstances in that position which enables their moderate degree of adhesiveness to come best into play, the result being the well-known ‘ rouleaux ’. The same is seen in the healthy blood of the cow. But in some animals, e.g. the horse, the adhesiveness of the discs is so great that they stick to one another by the parts that come first into contact, producing dense spherical masses large enough to be visible to the naked eye, like grains of red sand. These, falling rapidly through the lighter plasma, leave the upper part of the liquid free from red corpuscles before coagulation occurs, thus giving rise to the buffy coat, whereas in the cow the delicate network of rouleaux remains suspended, and no buff occurs.

I am greatly surprised to learn that the cause of the buffy coat is stated in some textbooks to be slowness of coagulation. Special slowness of coagulation does not occur in buffing blood ; nor, if it did, would it explain the phenomenon. In whipped horse's blood the red discs aggregate into dense masses as in blood freshly drawn, and falling rapidly soon leave a deep layer of serum. In whipped cow's blood, rouleaux forming in the serum as in the plasma, there will be found, if the animal was healthy, only a thin superficial serous layer, even after a lapse of twenty-four hours.

I once drew blood from a donkey into two similar glass vessels, one empty, the other half-full of water. The diluted blood and the undiluted clotted in exactly the same time. But whereas in the normal blood there happened to be an unusually thick layer of buff, comprising nearly two-thirds of the whole mass, the watered blood gave no buff, and the microscope showed that the red corpuscles had lost their natural adhesiveness.

Human blood, as is well known, shows the buffy coat in some states of inflammation. But it may also occur in anaemia.[1] And it may well make our profession humble to reflect that in days within living memory buffing of the clot was regarded as an indication for further withdrawal of the vital fluid by venesection.

To return from this digression : adhesiveness of the corpuscles, both red and white, was seen in the vessels of an irritated area of the frog's web, as in blood outside the body. But in a perfectly healthy part no such condition was observed. A string tied round a frog's thigh of course made the blood in the vessels of the foot motionless ; but on the slightest touch of the web the

[1] In the only case of anaemia in which I examined the blood microscopically I found the red discs extremely adhesive.

corpuscles, both red and white, moved along with the plasma with the most perfect freedom.

But I was not altogether satisfied with this evidence of their entire absence of adhesiveness within healthy vessels, because the aggregation of the red discs in the frog is of a somewhat indefinite character. I therefore sought further light upon the point in the mammalian bat. Having placed one under chloroform and extended one of its wings under the microscope, I temporarily arrested the circulation by compressing the main vessels of the limb ; and on examining one of the veins I was much disappointed to see the red corpuscles of its contained blood aggregated. It seemed possible, however, that the part of the membrane which I was examining might be suffering mechanical irritation from pressure between the glass slide on which it rested and the cover-glass which it was necessary to use with the high magnifying power required for the bat's wing. For those were not the days of immersion lenses. I therefore made arrangements to guard against the possibility of such an occurrence ; and now, to my great joy, I beheld the red corpuscles, which lay motionless in a considerable venous channel, distributed uniformly through the plasma, without the slightest appearance of aggregation.

The animal having been killed immediately afterwards, I examined a drop of blood from its heart. The contrast with what I had seen in the healthy living vessel was most striking ; the red corpuscles presenting a degree of adhesiveness such as I had never before seen equalled, whether outside the body or within the vessels. When forced to separate from each other by pressure made upon the cover-glass, they became drawn out like threads of a viscid liquid before becoming completely detached. The animal had been suffering from a bad compound fracture in one of the wings. Whether the great adhesiveness of the red discs of the shed blood was due to inflammation caused by the injury, or whether such a condition is normal to the bat, as it is to the horse and the ass, I do not know.

By such facts it seemed to be established that the stasis of the blood in an irritated area, that is to say, the accumulation of the blood-corpuscles, both red and white, in the vessels of that area, is due to a tendency on their part to adhere to each other and to the walls of the vessels ; that they do this by virtue of an adhesiveness or viscidity which they do not manifest at all within the vessels of a perfectly healthy part, and which, while varying in degree with the severity of the irritation, never seems to exceed that which is observed in blood outside the body.[1]

What was it that induced the blood corpuscles to assume this adhesiveness

[1] Vide *Phil. Trans.*, 1858 (see vol. i, p. 217).

under irritation ? It was clearly not the result of direct action of the irritant upon them. When the inflammatory congestion, as I ventured to term it, was not carried to its extreme degree, the corpuscles, though closely packed, still moving sluggishly along, successive portions of blood, as they passed through the affected spot, were successively affected in the same way, it might be for hours after the irritant had ceased to act. And some of the agencies which produced the effect, such as gentle warmth and mechanical disturbance in the shape of moderate pressure, were not of a nature to act chemically upon the blood-cells, and could not possibly leave behind them among the tissues any active substance.

The tissues, as distinguished from the blood, were therefore the parts primarily and essentially affected by the action of the irritant. And we have seen that, in their relation to the blood-corpuscles, they approached more or less closely, according to the degree of the irritation, the behaviour of ordinary solids, such as glass, as distinguished from the living structures. The natural inference was that they had lost more or less, for the time being, certain special properties which they possessed when in active health as constituent structures of the living body. In other words, certain of their vital functions were temporarily in abeyance. I say temporarily because the extreme degree of inflammatory congestion, in which the capillaries appear as homogeneous scarlet threads of densely packed red discs, is susceptible of complete recovery by resolution if the action of the irritant has not been pushed too far.

The same conclusion followed naturally from a consideration of the properties of irritants. Greatly as they differ in their nature, whether physical, as mechanical violence, heat, and the electric shock, or chemical of the most varied characters, one feature they have all in common ; if pushed far enough they destroy the tissues on which they act. Extreme inflammatory congestion is the state which they produce when their action is just short of the lethal degree ; and it could hardly be doubted that the state of the tissues just short of death must be one of impairment of vital power.

This view was beautifully confirmed by a series of observations to which I was led by a most unlooked-for experience. Before I had adopted the method, which I have described, of obtaining a perfectly tranquil state of the frog's foot, I sought to study the local effect of an irritant by placing on the middle of the web a small piece of moistened mustard, which could not be shifted in position like a drop of liquid when the animal struggled. On removing the mustard after a while to observe its effects, I was astonished to see the part of the web on which it had lain, not only affected with inflammatory congestion, but totally different in colour from the rest of the web in consequence of a dif-

ference of arrangement of its pigmentary constituents. Where the mustard had rested, the pigment appeared as a delicate black network among the tissues, causing an extremely dark appearance; whereas in the rest of the web it was gathered into small round spots, which interfered little with the pallor of the other structures. I at once saw that I had before me direct ocular evidence of an effect of the irritant upon the tissues. The circumstance that I had applied the mustard to one spot only of the web, had revealed what had escaped the notice of the many previous observers who had studied the circulation in the frog. I afterwards learned that changes of colour due to pigmentary variation had been observed in Germany in the green tree-frog by Von Wittich, who had attributed them to contractions and relaxations of chromatophorous cells, more or less analogous to what is seen on a large scale, visible to the naked eye, in the skin of cephalopods. Very different were the real pigmentary functions in the frog. The colouring matter, which was in the form of granules of extreme minuteness, was contained in cells with offsets that rapidly broke up into ramifications of exquisite delicacy, anastomosing freely with each other and with those of other branches and of neighbouring cells, only visible when the frog was at the darkest, when they appeared, under the highest magnifying power at my disposal (a fine $\frac{1}{12}$ of Powell and Lealand's), as fine homogeneous black lines, in which the closely packed granules were not individually discernible. Under these circumstances the bodies of the cells and their principal offsets were so cleared of pigment as to be almost colourless, so that it was difficult to define their contour.

On the other hand, when the animal was at the palest, the pigment-granules were massed together into a circular disc, which did not occupy the whole of the body of the cell, being apparently grouped round its nucleus, while the offsets and their ramifications were quite colourless. Any intermediate degree between these extremes of complete diffusion and perfect concentration of the pigment-granules might occur, with corresponding differences in the tint of the animal.

Camera-lucida sketching here stood me in good stead. I doubt if any one would have credited my description had I not been able to support it by such evidence. For here was a function entirely new to physiologists. In muscular contraction the entire mass of the cell shrinks, and in ciliary action, the only other visible form of motion then known to occur in animal tissue, the part concerned moves as a whole, so far as we are able to observe it; in the pigmentary changes the form of the cell remained unaltered, but one of its constituent materials was seen to be transferred from place to place among the rest. But drawings made with the camera of a cell in suc-

cessive stages of concentration of the pigment admitted of only one just interpretation.[1]

These changes in the disposition of the pigment accommodate the tint of the animal to that of surrounding objects. A dark frog placed in a white earthen basin in sunlight soon assumes a dull yellow colour, and a pale one is not long in becoming black in a covered earthen jar.

It was very interesting to find that light produces these effects, not by direct action upon the skin, but indirectly through the retina and optic nerve. A hood of black cloth, carefully arranged so as to exclude light from the eyes without obstructing respiration, entirely prevented a dark frog from becoming pale in bright sunlight. I was naturally desirous of ascertaining through what efferent channels the nervous impulse that caused concentration of the pigment on exposure to light was conveyed from the brain to the foot. Division of the sciatic nerve had no effect whatever upon the colour of the limb. I then tried cutting through all the structures in the thigh except the bone, the femoral artery and vein, and the sciatic nerve. This also had no influence. But when I added to the latter procedure the section of the sciatic, the animal being then pale, it gradually grew dark below the seat of operation, till in no long time it presented from the toes to the wound as great a contrast with the rest of the body as if that part had been covered with a miniature black stocking. Thus the regulation of this function, which is probably closely allied to the action of the cells in nutrition, was not carried on exclusively through special nervous channels, as is the case with the contractions of the voluntary muscles, but one nerve could take the place of others in the duty.[2]

Light was not the only agency that induced pigmentary concentration. It might take place rapidly during struggling of the animal, and I once saw a frog grow pale in its efforts to avoid capture. Here mental emotion perhaps came into play, if we may use such an expression regarding the frog.

It seems quite astonishing that nervous action should make the pigment-molecules rush thus rapidly to the centre of the cell from its remotest and finest

[1] Max Schulze had not yet described the movements of animal protoplasm; and if he had done so, this could have gone but a little way in explaining the phenomena described in the text. The gushing out of homogeneous pseudopodia from the granular body of an amoeba may, however, be of an allied nature. I made attempts to see the movement of the pigment-granules in cells in which concentration was going on; but their extreme minuteness, together with the excessive rapidity of their apparent motion under the high magnifying power requisite, made them generally elude observation. I fancied I saw an indefinite rush of something through the clear space around the already accumulated mass, but I could not be sure. On one occasion, however, I saw some individual granules leave the mass and make excursions into the colourless liquid, as I could not doubt it to be.

[2] Vide *Phil. Trans.*, ibid. (see vol. i, p. 45).

ramifications. Yet a sudden gush of tears or outburst of perspiration, although familiar, is perhaps not less wonderful.

Concentration of the pigment took place, as we have seen, under nervous influence, and diffusion on its withdrawal. But diffusion was no mere passive phenomenon, such as might follow according to any ordinary arrangement of matter, when the agency that caused the grouping of the molecules ceased to operate. The transference of the granules from the body of each cell to its remotest ramifications, and their close packing there, were an act such as a living organism alone could have effected. Pigmentary concentration and diffusion were vital functions of a profound character concerned with the relative distribution of different constituents of the cells. Yet from the very happy circumstance of the conspicuousness of the pigment, the results of their activity could be observed with the utmost facility, and their behaviour in relation to inflammatory congestion easily studied even under a low magnifying power.

The pigment-cells pervade the skin and subcutaneous tissue of which the frog's web consists, and are especially numerous about the blood-vessels, round which their branches twine abundantly. They must, therefore, be acted on along with the vascular parietes by anything applied to the surface of the membrane. And to state shortly the result of many experiments, I found that any agency, physical or chemical, which caused the blood-corpuscles to lag behind the liquor sanguinis in the part on which it operated rendered the pigment cells in that particular area incapable of discharging their functions. Whatever might be their state at the time of the experiment, whether in full diffusion, complete concentration, or any intermediate condition, so they remained in the irritated spot, while in surrounding parts of the web, as in the body generally, they changed as usual in obedience to differences of illumination or other circumstances. At the same time they were not killed: for if the irritation had not been too severe, they recovered their full activity when resolution occurred.[1]

[1] I have in rare instances seen an irritant cause diffusion from a state of concentration as a preliminary effect. This was unmistakably the case on one occasion when mustard was employed. The pigment was in an intermediate (stellate) state when the application was made. In a narrow ring round the mustard, where the volatile oil could only act extremely mildly on the web, the stellate condition gave place to complete diffusion; whereas under the mass, where the irritant had acted at once with full energy, the stellate appearance remained unchanged. Inflammatory congestion, however, had been produced in the ring of full diffusion as well as in the more strongly irritated area. It happened that complete concentration afterwards took place in the rest of the web, while the irritated areas retained the appearances above described. It seems probable that the diffusion under the slighter irritation may have been the result of the nerves in the irritated part being paralysed before the pigment-cells.

As is commonly the case with more specialized structures, the pigment-cells are a delicate form of tissue, and are more readily killed than other constituents of the web. Hence, if care is not taken to avoid pushing the action of the irritant too far, it will be found, after resolution has taken place, that

Thus the pigment-cells afforded ocular demonstration of the truth, to which I was otherwise led by inference, that an irritant, when producing inflammatory congestion, prostrates for the time being the vital energies of the tissues on which it acts.

It is to be observed that mere paralysis of the nervous apparatus of the irritated area would have been followed by diffusion of the pigment, as occurred after section of the nerves in the thigh, so that the suspension of diffusion as well as concentration shows that the special pigmentary functions had been arrested.

It was of course a familiar fact that nerves may be temporarily paralysed by the direct action of pressure, cold, and other agents upon them. But, so far as I am aware, it had not been known that the tissues generally are liable to be thrown into a state of suspended vital energy by injurious influences.

An experiment upon another form of tissue seems so illustrative of this subject that I am induced to relate it in detail. It was an attempt to study the effect of warmth upon the ciliated epithelium of the frog's tongue. It was easy to obtain the material for examination by gently scraping the surface of the organ and diffusing the product in a drop of water. Individual isolated cells were then to be seen with their cilia in motion, which might continue for a considerable period. But special arrangements were necessary in order to avoid killing them with the warmth, to which, as we have seen, the tissues of the frog are peculiarly sensitive. I succeeded by arranging them in a film of water between two delicate cover-glasses, the whole mass being so thin that it could be very quickly heated and as rapidly cooled. The object being placed under the microscope, I interposed a small cautery at a low black heat between the reflector and the stage and watched the result. The ciliary motion, which had been somewhat languid, became at once increased in rapidity, but resumed its former rate if the cautery was at once withdrawn. If, however, the application was somewhat longer continued, the active motion soon gave place to a state of complete rest, in which the cilia stood straight like the hairs of a brush. The hot iron being removed the instant that this effect was observed, slight indefinite movement soon began to show itself in individual cilia ; and before long all were again in action as before the heat was applied. If the cautery was made somewhat hotter the motionless condition was produced almost immediately, preceded by a momentary period of excessively active motion. But if the warm application was immediately suspended, recovery occurred, as in the former case. And the same experiment might be repeated again

the pigment-cells never recover ; the collections of pigment gradually lose their sharpness of outline and are ultimately absorbed, leaving a permanently white spot in the web.

and again on the same cells with the same results. But if the warmth was allowed to act for a slightly longer time, or the cautery was made still hotter, recovery never took place, and the bodies of the cells swelled up through endosmotic imbibition of water, having lost all life and obeying the ordinary laws of chemistry.

This simple experiment was in various ways instructive. It indicated that ciliated epithelium cells, like the pigment-cells, when acted on by a destructive agency to a degree just short of that which is lethal, are thrown into a state in which their vital functions are suspended but not irretrievably lost. It also showed that the cells which compose the animal organism are individually capable of recovering from this state of suspended vital energy, without any aid from the general circulation or the nervous system.

It further illustrated the important fact that a most injurious agent when operating very mildly may stimulate function without impairing power.[1]

Active congestion, or arterial dilatation with consequent free flow of blood through the capillaries, is an early and prominent symptom of inflammation of a vascular part in man. Unlike the morbid condition which is produced by the application of irritants to the frog's web, it is brought about indirectly through the nervous system. A striking illustration of this was presented in a case which occurred at the period to which I have been referring. A scirrhous mamma had been removed by transverse incisions, together with a considerable amount of integument ; and the cutaneous margins had been brought together, in spite of a good deal of tension, by means of a few stitches. Two days later I found the lips of the wound gaping slightly ; but the sutures, though subjected to much traction, were still holding ; while the skin presented an inflammatory blush extending both upward and downward from the wound, so that it occupied an area of about four inches in breadth. I removed the sutures, and I particularly noticed that no blood escaped from any stitch-track. The procedure occupied about two minutes and (to quote from a note taken at the time) ' no sooner had I done this than I observed that the redness had almost entirely disappeared ; most parts that were before apparently intensely inflamed being now pale '. The irritating agents acted directly on only a minute portion of tissue ; but they induced widespread active congestion, which subsided at once on their removal. Such results could only have been brought about through the agency of the nervous system.

As I before had occasion to remark, active congestion takes place throughout

[1] It would appear that all agents that act with destructive effect upon the tissues produce suspension of vital energy without loss of life when operating in a minor degree. Whether all such agents are also stimulants of function when in a still milder form is quite another question.

the frog's web when an irritant is applied to any part of it. It was therefore possible to study the phenomenon upon that animal. It was not at that time clearly known by what mechanism the constriction of the arterioles was effected, or by what part of the nervous system it was regulated. Kölliker had recently made his great discovery of the fibre-cells of involuntary muscle, and had described them as existing along with elastic tissue in the middle coat of the larger arteries ; but the trustworthiness of his observations had not yet been by any means universally recognised, and the structure of the ultimate arterioles, as compared with the capillaries, had not been ascertained.

I found, on dissecting out the vessels from between the layers of the frog's web, and examining them with a high magnifying power, that whereas the capillaries showed only a thin, apparently homogeneous wall beset with occasional nuclei, the finest arteries exhibited three coats, of which the middle one was composed of muscular fibre-cells wrapped spirally round the lining membrane. A more efficient mechanism for their constriction could hardly be conceived.[1]

As regards the regulation of the arterial contractions, Bernard's classical experiment of inducing turgescence of the vessels of the ear by section of the sympathetic in the neck, and Waller's converse observation that galvanic stimulation of the distal end of the divided nerve made the distended vessels shrink and the ear assume unwonted pallor, had demonstrated the great fact of nervous control over the local circulation ; but it was still a subject of discussion what part of the nervous centres exercised the function.[2]

In entering on the inquiry, I first divided the sciatic nerve, a proceeding which had been stated on high authority to cause relaxation of the arteries of the web. The immediate effect of its division was, indeed, some enlargement of their channels, but this very soon passed off. I then resorted to operations on the roots of the spinal nerves and on the medulla. And, not to weary you too much with details, I may say that removal of all that part of the spinal cord which gives off branches for the hind legs, caused the arteries of the web to relax completely and to remain permanently of about the same calibre as the veins. But if any portion that furnished nerves to the posterior extremities was allowed to remain, whether a little caudal segment or a small anterior part, the arteries resumed, after temporary dilatation, their ordinary and varying dimensions.[3]

It was thus shown that the cerebro-spinal axis is the centre that presides

[1] Vide *Trans. of the Royal Society of Edinburgh*, vol. xxi, part iv (see vol. i, p. 15).
[2] For authorities on this question, vide *Phil. Trans.*, ibid., pp. 607 et seq. (vol. i, p. 27).
[3] Vide *Phil. Trans.*, ibid.

over the contractions of the arteries of the foot, and that the function is exercised by the entire posterior half of the cord.

The very transient effect of section of the sciatic proved that, as is the case with the pigmentary functions, one nerve can take the place of others in the duty. And I found that even after division of all the soft parts of the thigh except the main artery and vein, the vessels of the webs soon recovered their contractile power ; showing that the control of the cord over the arteries can be kept up in an extensive region through quite insignificant nervous twigs. We can thus understand how a flap of skin raised in a plastic operation in the human subject may have its circulation duly regulated through a narrow neck of attachment.

An experiment that greatly pleased Dr. Sharpey would seem to indicate that the vaso-motor function for the hind legs is also discharged by the most anterior part of the cord. A frog having been arranged as before described, the point of a fine needle, curved at the end, was introduced into the wound behind the occiput, so as to prick for an instant the divided medulla. The eye of the observer being over the microscope while this was done, the arteries of the web were seen to contract to complete obliteration of calibre, as in the first experiment with warm water.

The contraction of the vessels caused on that occasion by the application of gentle heat to the web was now explained as a ' reflex action ' through the spinal cord. Their dilatation under irritation remained to be accounted for. In describing that first experiment, I stated that the extreme constriction of the arterioles was followed by relaxation to a larger calibre than they had before the water was applied ; suggesting the idea of fatigue after exertion. I have now to add that, if the warmth was longer continued, the subsequent relaxation was more marked and of longer duration ; and if the water was made somewhat hotter the contraction that preceded the dilatation was so transient as to be barely discernible.[1]

We seem to have here an exact parallel to what occurred as the result of the action of heat upon the ciliated epithelium. And the natural view seemed to me to be that the ganglion cells of the cord concerned in the arterial contractions were affected by the nervous impulse conveyed to them by the afferent fibres according to the same law that governed the direct action of heat upon the epithelium cells ; increased activity or suspension of function being induced according to the degree of energy of its operation. I incline still to believe that this was a correct interpretation of the phenomena of active congestion.

[1] Brief contraction of the vessels, followed by dilatation, had been previously observed by others as the result of the application of irritants to the frog's web.

Inflammatory congestion also may be brought about by nervous agency. This fact being of fundamental importance, and not perhaps universally recognised by pathologists, I may describe briefly two unpublished experiments with regard to it which I did shortly after the time of which I have been speaking. Inflammatory phenomena being of a very languid character in the frog, I had resort to a higher animal. One of the experiments was simply passing a silk thread through a fold of skin in a rabbit's back and knotting the ends together. When forty-eight hours had elapsed, the animal having been killed, I removed the portion of skin concerned and examined its under surface. The thread was covered with a yellow line of lymph, around which there was intense scarlet redness for about a quarter of an inch in every direction, contrasting strongly with the paleness of the healthy structures around. And on microscopic examination I found that this depended (to quote from my notes of the time) 'partly upon ecchymoses, but chiefly upon well-marked inflammatory congestion of the minutest vessels of the subcutaneous tissue and the deeper parts of the skin'.

The other experiment was performed twenty minutes before the first, upon a part of the same animal which, being more sensitive, was more likely to show the effects of nervous disturbance. By means of a fine sewing-needle I passed a delicate thread of silk through the superficial layers of the left cornea, and cut the ends off close with scissors. Next day the eye was much inflamed and its condition was aggravated on the day following, while the other eye remained healthy. As I have already said, the rabbit was killed on the expiry of forty-eight hours. This having been done by pithing, I at once divided the blood-vessels in the neck while the heart was still beating, so as to allow all blood that was free to flow to escape from the head. I then removed the two eyes and cut them both across transversely midway between the cornea and the optic nerve, and compared the inflamed eye with the healthy. I will not detain you with a description of the anterior halves of the globes, though they were very interesting, but will at once speak of their posterior portions, more remote from the part where the exciting cause had been in operation on the left side. In that eye the retina was much more readily detached than in the right, and showed small spots of ecchymosis, while the blood-vessels were more conspicuous. The two chloroids presented a striking contrast; 'the vessel in the right eye' (to quote my notes again) 'being not at all conspicuous, while in the left eye the membrane was scarlet; and this depended not merely upon fullness of red vessels but upon darker tint of their contents in consequence of excess of the corpuscles.'

It is matter for discussion how inflammatory congestion is brought about

by nervous action. It may be doubted whether active congestion could alone give rise to it, though it is by no means inconceivable that the excessive supply of the nutrient fluid might in time exhaust the tissues by over-stimulation, and so bring about more or less of that impairment of vital energy which we have seen reason to regard as the essential cause of the blood-corpuscles lagging behind the liquor sanguinis.

Or it may be that the nerves produce this weakening effect upon the tissues by immediate action upon them. From that point of view, the proof afforded by the pigment-cells of the influence of the nerves over processes going on within cells seemed to me peculiarly interesting. And we can conceive of nervous impulse impairing their energies either by over-stimulation followed by exhaustion, or by immediate prostration of their powers as by an electric shock.

That the latter idea is not altogether out of the question seems to follow from a kind of experience familiar to surgeons. I will mention one instance of this which produced a great impression upon me. A healthy man, in the middle period of life, had been operated on by lateral lithotomy. All went perfectly well till about ten days had elapsed, when the renal secretion, which had passed through the wound since the operation, flowed for the first time through the natural channel. In those days, when lateral lithotomy was the routine treatment of calculus, it was well understood that the mucous membrane becomes in a few days unaccustomed to the urine, which then acts upon it with irritating effect, and the result may be a violent general nervous commotion in the shape of a rigor. This may be immediately followed by complete suppression of secretion by the kidneys; and if this does not pretty soon pass off it is fatal. Such was the case with the patient to whom I am referring. In spite of hot applications to the skin—which sometimes work like a charm in such circumstances, operating, as it would appear, by distracting, so to speak, the attention of the nervous system from the affected organs—that man died within a few hours of the rigor. On post mortem examination the kidneys presented on section an appearance that I have never forgotten; scarlet redness throughout what in other respects appeared to be perfectly sound structure.

The previous healthiness of the patient seems to preclude the idea that this grave disorder of the kidneys could have existed before the rigor. We are therefore led to believe that the prostration of vital energy which inflammatory congestion implies was caused by the irritation in the urethra. If such was the case, the remoteness of the kidneys from the source of disturbance makes it certain that the disorder was brought about through the nervous system. This effect could not possibly be produced, like arterial relaxation, by failure of the nerves to act. For we know that the tissues retain their vital

energies for a considerable period after entire severance from the body: as is illustrated by the success of Thiersch's method of skin-grafting. We are therefore driven to the other alternative, and conclude that the inflammatory congestion of those kidneys was caused by nervous action upon the renal tissues. And the suddenness with which the effect was produced strongly suggests the view that the prostration of their vital power was the primary effect of an unwonted nervous impulse.

Abnormal effusion of liquor sanguinis from the vessels, another marked feature of acute inflammatory disturbance in man, would seem a natural result of any degree of inflammatory congestion. I used to illustrate to my class by a simple experiment the enormous increase which takes place in the pressure of a liquid upon the walls of a tube through which it is flowing, when an obstacle is opposed to its passage. When, therefore, the corpuscles begin to block the capillaries the plasma will naturally be forced in undue quantity through their porous walls.

When inflammation assumes an intense degree, the effused liquor sanguinis has the peculiarity of being coagulable, producing by its solidification the characteristic 'brawny' swelling of the parts among which it is poured out. In this respect it differs from the normal plasma forced by pressure through the walls of healthy capillaries as the result of venous obstruction. Here the swelling has the 'doughy' character of oedema, a condition also caused by inflammation of a mild degree. To that point I shall have occasion to refer again.

I designated by the title 'direct inflammation' the morbid state produced by the direct operation of noxious agents upon the tissues, as distinguished from inflammation brought about through the medium of the nervous system. This distinction appears to me to be of great importance; and it enables us to understand what would otherwise be quite unintelligible. One beautiful instance of this is the behaviour of a recent wound in tissues previously healthy. When our means of arresting bleeding were less complete than they are at present, it was no uncommon thing to be summoned a few hours after an operation on account of haemorrhage. It was a sad thing to have to tear asunder the lips of a wound already well glued together by lymph, in order to gain access to the bleeding-point. This lymph was neither more nor less than liquor sanguinis which had been effused from the cut surfaces and had coagulated. From the quality of the effusion we should suppose that we had to deal with inflammation of a very intense character. Yet the lips of the wound were perfectly pale, entirely free from the active congestion which is the very earliest sign of inflammatory disturbance. How could this inconsistency be reconciled? Very

simply, as I believe, by aid of the principles which we have been discussing. Mechanical violence is a noxious agency producing effects proportionate to its degree. A very blunt implement passing through the tissues kills the surface of the parts which it divides ; and in former days we had to poultice a ' contused wound ' till the sloughs separated. A sharp knife does not destroy any part of the tissues, but it throws them in a microscopically thin layer into a state of intense inflammatory congestion, attended with effusion of coagulable liquor sanguinis. But this noxious agency is only momentary in its operation. It has no time to cause active congestion through the nervous system, but at once leaves the injured tissues free to recover by virtue of their own inherent powers. If the instrument be very sharp the layer of lymph will be very thin, unless some other disturbing cause come into play. But it is always sufficient in amount to serve the beautiful purpose of adhesion.

It is comparatively rarely that direct inflammation is met with thus pure and simple in practice. The two forms, the direct and indirect, are commonly more or less associated. Thus putrid discharge in a wound is an acrid irritant, as I once experienced personally in the keen smarting of an abrasion on the back of my hand, smeared accidentally with the pus of a stump that I was dressing. Hence during the period that elapses before the divided tissues are clothed with that wonderful protecting layer which we term granulations, such discharge causes direct inflammation in the structures on which it acts immediately, while it also induces in them and in neighbouring parts inflammation through the nervous system.

When Marion Sims had published his remarkable success with the silver suture in gynaecology, I resolved to give it a trial in general surgery. At that time, as assistant surgeon in the Royal Infirmary of Edinburgh, I had charge of the Lock Hospital ; and one of the patients having an atheromatous tumour of the scalp, I removed it and brought the edges of the skin together with a silver stitch. No vessel required ligature, and the wound healed without suppuration. As the suture created no disturbance, I left it *in situ* for about ten days, when I took the patient over to Mr. Syme and showed him the skin about the wire perfectly pale and natural in appearance without a trace of discharge, whereas a silk stitch would within four days have infallibly caused suppuration, with surrounding redness. Mr. Syme at once recognised the importance of the facts, and from that day forward the silver suture was used for all wounds in the clinical wards, until, some years later, antiseptic measures caused it to give place to the more convenient and no longer hurtful silk.

In thinking over this striking difference between the effects of the two kinds of suture, it seemed to me clear that it depended on the silk imbibing

blood and serum, which, undergoing decomposition in its interstices, grew more irritating the longer the process continued ; whereas the metal gave no hold to the organic liquids, which were shed unaltered as fast as they were effused. From these and other analogous considerations, I taught my class at that time that decomposition of the organic liquids was the essential cause of suppuration.

The coagulation of the blood, while it is a matter of fundamental importance in physiology, has peculiar interest for the surgeon, on account of the special feature of coagulability of inflammatory exudations and the part played by lymph in the healing of wounds and various other pathological phenomena, such as the sealing of divided arteries by blood-clot. Towards the close of the investigations which I have been describing there was published another successful Astley Cooper Prize essay, *Coagulation of the Blood* having been the subject selected by the judges for the competition. The author of this dissertation, the late Dr. Richardson, propounded the new theory that the solidification of blood shed from the vessels was due to the escape of ammonia, which, as he believed, held the fibrine in solution. I was at first much struck by the evidence with which he supported this view, and my first experiments on the subject were made with a view to strengthening that evidence where it seemed to me weakest.

In one of these, a sheep having been placed under chloroform, I sought by means of a common tourniquet to constrict the thigh so extremely as to prevent the ammonia from escaping when the vessels were divided, and so keep the blood fluid in spite of amputation. Rigidity of the muscles prevented me from carrying out my intention ; but I tied a bandage firmly round the foot, below the joint where the butcher removes it, so as to retain the blood, and, as far as might be, the ammonia also. The foot being severed, I took it home, and, having raised a portion of the skin so as to expose a subcutaneous vein, I investigated the state of the blood in it. I found it indeed fluid, with one exception, full of significance, though I did not see its import at the time, viz. where the cord used by the butcher for tying the feet together had pinched the veins against the bone, there, and there only, was the blood in them coagulated. I remember being a little disappointed, as well as puzzled by that appearance. It was not in harmony with the theory in which I was at the time disposed to believe. And yet how replete were the facts with possible instruction ! Compression of the veins had certainly given no opportunity for escape of ammonia. It is equally certain that the cord did not make the blood coagulate by any direct action upon it : for the cord, so long as it remained in position, kept the parts of the veins which it compressed empty of blood. It is clear that the effect was due to the action of the cord upon the walls of

the vessels. Not that it had wounded them, nor is there any reason to suppose that it had killed them. No doubt if the animal had been released instead of slaughtered, the veins would in due time have recovered. But the mechanical violence which the hard round cord exerted, being pretty severe and long continued, had prostrated for the time the vital energies of the tissues on which it had acted ; and we had, in coagulation of the blood, a repetition of the class of phenomena we had studied in the blood-corpuscles.

But how was it that the blood remained fluid in other parts of the vessels ? To my surprise I found that the same continued to be the case for days afterwards. And thus accident led me to recognise what I afterwards found to be the general rule, viz. that the blood, though in mammalia it coagulates soon after death in the heart and main trunks, remains fluid for an indefinite period in minor branches. The clotting in the heart had been an object of familiar observation in post mortem examinations in the human subject, and it seems to have been assumed that the same thing occurred throughout the vascular system.

The sheep's foot, with the blood retained in its veins by a bandage applied before the animal was slaughtered, afforded the opportunity for very simple, but instructive experiments on the nature of the relations between the living vessels and their contained blood. For that the veins retained their life, even after the lapse of more than twenty-four hours after severance of the foot from the body, was shown by their shrinking by muscular contraction on exposure.[1]

Thus I found that a piece of glass introduced into a vein occasioned coagulation in its vicinity. The end of a sewing-needle pushed through the wall of a vein otherwise uninjured, became after a while encrusted with a layer of fibrine deposited upon the part within the vessel, while the rest of the blood in it retained its fluidity.[2] On the other hand, having injected air into the vessels on another occasion, I found seven hours later that their contents were a frothy mixture of blood and air, the walls of whose bubbles were fluid, but solidified when shed. Sir Astley Cooper had been of opinion that the living vessels kept the blood within them fluid by acting in some way upon it—in other words,

[1] As regards the ammonia theory, an experiment which proved universally convincing was this : Having exposed a vein in the sheep's foot, I pressed the blood out of it at one place, and applied liquor ammoniae to the empty portion, protecting neighbouring parts of the vessel from the vapour with olive oil. After sufficient time had passed for the volatile alkali to fly off, blood was allowed to return to the part on which the caustic liquid had acted. There it soon coagulated : the very substance a mere trace of which should have kept it fluid according to the theory in question having brought about its coagulation by injuring the tissues of the living vessel.

[2] The results of experiments of this kind vary considerably according to the time which has elapsed after the foot was removed from the body : for the blood undergoes pretty rapid impairment of its coagulability within the vessels of the severed part, and finally loses it altogether. It then, of course, remains fluid long after the veins have lost all life.

his view implied that the blood had a spontaneous tendency to coagulate, which was held in check by the active operation of the living tubes that contained it.[1] Facts such as I have just mentioned seemed to me to indicate that the ordinary solid was the active agent, determining the formation of fibrine as a thread does the deposition of sugar candy; while the healthy living tissue had the remarkable peculiarity of being destitute of this general aggregating property of solids, behaving rather like the self-repelling particles of gases.[2]

It was not only in vessels of small size, like those of the sheep's foot, that the blood remained fluid in parts severed from the body. I found that the same was the case in veins of the dimensions of the jugular of the ox or the horse, and this in spite of their entire detachment from surrounding structures. The vessel being exposed after the animal had been felled at the abattoir, two ligatures were applied in order to retain the blood in it, after which it was removed and taken home with as little disturbance as possible. The blood in it retained its fluidity for upwards of twenty-four hours, affording opportunity for most instructive experiments. Of these I must content myself with describing one. A portion of an ox's jugular with its contained blood being held vertically, the upper part was removed along with its ligature, and the lips of the now open venous compartment were held apart with forceps by aid of an assistant, while a thin glass tube, of rather smaller calibre than the vein and open at both ends, was passed down into the vessel with the utmost steadiness, so as to disturb the blood as little as possible. The upper end of the tube had been drawn out with the blow-pipe to much smaller size and a short piece of india-rubber tubing adapted, so as to admit of clamping with catch-forceps. When blood appeared at the end of the caoutchouc tube the clamp was applied. The whole apparatus was then rapidly inverted and the piece of vein removed, leaving the blood in a vessel of ordinary solid matter without any contact of living tissue. The glass tube was steadily clamped to a retort stand, and its orifice covered with a loose cap of gutta-percha tissue to exclude dust, after which all was left undisturbed for twenty-four hours. On then turning out the blood, I found it all fluid except a layer of clot about one-eighth of an inch in thickness, which encrusted the interior of the tube, and also a little clot at the surface, which

[1] Brücke, of Vienna who had also competed for the Astley Cooper Prize, had arrived at a similar conclusion. He experimented largely with the turtle's heart, which, as in cold-blooded animals generally, retains its life long after removal from the body; the blood in its cavities at the same time retaining its fluidity. I had not seen Brücke's important essay when the experiments referred to in the text were performed.

[2] It has since been shown by Freund, of Vienna, that an indifferent liquid, such as liquid paraffin, has a similar negative behaviour in relation to coagulation; so that, by proper management, blood may be kept fluid in a vessel of ordinary solid matter having its interior smeared with that substance. Professor Haycraft arrived about the same time at a similar conclusion regarding castor oil.

might be explained by some drying on account of the imperfect fitting of the cap. The fluid part of the blood soon coagulated.

The result of this experiment seemed to me of itself sufficient evidence that the blood requires no action of the living vessels to maintain its fluidity, and that the hypothesis of such action was superfluous.

At the same time the extreme care required in order to ensure the success of such an experiment indicated the subtilty of the influence of an ordinary solid in bringing about coagulation. A very simple experiment, performed in a butcher's establishment on the way from my father's house at Upton to deliver the Croonian Lecture before the Royal Society, illustrates the same thing. I received blood from the throat of an ox into two similar open earthen jars (gallipots), and slowly moved a clean glass stirring-rod through the blood of one of them for a second or two, and then left both vessels undisturbed.

In the course of a few minutes the blood that had been thus gently and briefly stirred was a mass of coagulum, while the unstirred blood was still fluid, except a thin layer of clot encrusting the wall of the jar. In course of time it also coagulated completely. Now we know, from the experiment with the ox's jugular, that coagulation is propagated with extreme slowness, if at all, from a clot in blood perfectly undisturbed. The earlier coagulation of the main mass of the stirred blood was, therefore, not caused by propagation of the process from a layer upon the surface of the jar, but must have been the result of the brief agency of the glass rod.

A little before the delivery of the lecture referred to,[1] I became aware of the recent very important observations of Schmidt, who showed, as had been foreshadowed many years previously by Andrew Buchanan, of Glasgow, that normal liquor sanguinis does not, as had been supposed, contain fibrine in solution but only one constituent of that substance, termed by Schwann fibrinogen, the other constituent being derived from the blood-corpuscles. The ordinary solid, therefore, in determining coagulation, does not cause the deposition of fibrine already formed, but so influences the corpuscles as to make them give up an ingredient necessary for the formation of that insoluble body.[2]

With this further light upon the subject, the conclusions derived from the experiments to which I have referred seem to explain the special coagulability of the exudation in intense inflammation. Under intense irritation the capillary walls will naturally be affected by the noxious agency as the veins of the sheep's

[1] Vide the Croonian Lecture, 'On the Coagulation of the Blood,' *Proceedings of the Royal Society*, 1863 (reprinted in vol. i, p. 109).

[2] Regarding the corpuscular elements of the blood which are concerned in supplying to the plasma the materials necessary for the formation of the fibrine and the chemical interactions of those substances, various important researches have since been conducted, in which I have had no share.

foot were by the constricting cord, and, like them, will act upon their contained blood as if they were ordinary solids. The plasma of that blood will therefore receive from the blood-corpuscles the material requisite for forming fibrine, and, passing through the pores of the capillaries with that addition, will constitute a coagulable exudation.[1]

On the other hand, if irritation is less severe, although the corpuscles acquire more or less adhesiveness, involving corresponding obstruction to the flow through the capillaries and consequent undue passage of liquor sanguinis through their walls, the constituent tissues of the vessels are not reduced to the condition in which they act like ordinary solids in relation to coagulation. This seems to follow from the uncoagulable character of the effused fluid. For we know that what used to be termed the serum of oedema or hydrocele is simply the normal plasma.

Adhesiveness of corpuscles and coagulation are both brought about by the operation of noxious agents upon the tissues of the part concerned. But it by no means follows that they are in all respects analogous phenomena. We have seen that normal blood has no innate tendency to coagulate, and needs no action of the tissues upon it to ensure its fluidity. But the blood-corpuscles may be naturally adhesive bodies, possessing a viscosity only kept in abeyance by some influence exerted upon them by the living tissues in their vicinity; and such appears to be really the case.

A very interesting observation which I made long ago, but to which I have not before directed attention in this point of view, shows that an extreme degree of adhesiveness of the red discs may exist within a blood-vessel, the walls of which are in perfect health with reference to coagulation. If a horse's jugular vein, obtained in the manner I have described, is suspended vertically, the blood in it remains fluid for an indefinite period, but the red corpuscles soon fall from the upper parts of the fluid, leaving a buffy layer of plasma, readily seen through the translucent wall of the vessel. And this behaviour of horse's blood implies, as we have seen, a high degree of adhesiveness of the red discs.

If we compare this with the perfect absence of grouping of the red corpuscles which was observed within a vein of the bat's wing, in spite of their extreme adhesiveness in the same animal in blood shed from the body, we cannot but be greatly struck with the contrast. As regards the circumstances of the two vessels, we see that in the bat's wing the vein was of small calibre, and was in its natural relations to surrounding structures; whereas the horse's jugular was of very large dimensions and isolated from the rest of the body.

It seems impossible that the adhesiveness of the corpuscles in the jugular

[1] I once ascertained the coagulability of a drop of clear fluid which had exuded from a recent contused wound, by drawing the point of a needle through it, to which it yielded threads of fibrine.

vein was the result of isolation of the vessel from other structures. For adhesiveness of corpuscles is not occasioned in the frog's web by amputation of the limb ; nor is it produced in the human subject by complete detachment of a portion of tissue ; as is clearly shown by the persistent healthiness of a piece of skin entirely transplanted in skin-grafting. We are therefore forced to the conclusion that the adhesiveness of the red discs in the horse's jugular, as contrasted with its complete absence in the vein of the bat's wing, was due to the larger size of the vessel in the former case. And the only way in which it seems possible to interpret this difference of behaviour of the corpuscles in the two cases is to suppose that they possess an innate and normal viscosity which is kept in abeyance by some action of the healthy tissues ; this action having a limited range of operation, so that, while effective for vessels of small size, it fails to influence the mass of blood in a large venous trunk. And I may remark, in passing, that it is only in the smaller vessels that absence of adhesiveness of the corpuscles is essential for the free transmission of the blood.

The mobility of the black pigment-granules of the frog has often struck me as extremely remarkable. Perfect absence of any tendency to aggregate on their part must be fully as essential to the freedom with which they move through the exquisitely delicate ramifications of their containing cells as want of adhesiveness of the blood-corpuscles is to their free transit through the capillaries, and I cannot but think that the two phenomena must be analogous. It may be, for aught we know to the contrary, that the pigment-granules may be themselves living entities. Their uniformity in size is in favour of such an idea. Our fathers would have been greatly astonished to learn that the chlorophyll grains of vegetables were, as has been shown in recent years, living organisms, multiplying by division like the nuclei of their containing cells ; and though the pigment-granules are much smaller, they must be greatly surpassed in minuteness by many microbes which, though hitherto invisible to us, we believe from analogy to be the causes of some infective diseases. But however this may be, the perfect mobility of the pigment-granules seems to me a special property which they possess as constituents of the healthy living body ; in other words, to use once more the expression which in the present state of our knowledge is indispensable, a vital property.

If this be so, we understand what would otherwise be very unintelligible, viz. that when the pigment-cells have their functions temporarily suspended by a noxious agent, the granules do not become diffused as they do when simply withdrawn from the influence of the nervous centres, but remain exactly as they were before the irritant was applied, whether fully concentrated, completely diffused, or in any intermediate state. If we suppose that the pigment-

granules, like the blood-corpuscles, acquire under irritation a tendency to mutual aggregation which they do not possess in health, it follows, as a matter of course, that when vital energy is suspended by the noxious agency, they will adhere together and retain their relative positions.

After being appointed to the Chair of Surgery in the University of Glasgow, I became one of the surgeons to the Royal Infirmary of that city. Here I had too ample opportunity for studying hospital diseases, of which the most fearful was pyaemia. About this time I saw the opinion expressed by a high authority in pathology that the pus in a pyaemic vein was probably an accumulation of leucocytes. Facts such as those which I mentioned as having aroused my interest in my student days in a case of pyaemia, made such a view to me incredible, and I determined to ascertain, if possible, the real state of things by experiment. I introduced into a vein of a living horse a short glass tube open at both ends, containing a piece of silver wire in which was mounted a little bit of calico, which I thought likely to give rise slowly to putrefactive change ; shutting off the portion of vein concerned from the general circulation by means of ligatures. After the lapse of some days I removed the venous compartment and found that the blood in it had undergone very remarkable changes. The limits of this lecture (which have been already too widely extended) make it impossible for me to enter into details, as I had hoped to have done, regarding the researches of which this was the commencement. I must content myself with stating the conclusion to which I was led at the time I am speaking of, and which was confirmed by later investigation, viz. that the introduction of septic material into a vein may give rise to the rapid development of large nucleated cells which, growing at the expense of the original constituents of the coagulum, convert it entirely into a thick yellow liquid. The pus so formed contains corpuscles which, like those which I sketched in the early case at University College, are not pus corpuscles in the ordinary sense or leucocytes, but the variously sized, more or less granular nuclei of the large cells, the pellucid bodies of which constitute the so-called liquor puris. Into the question of the origin of these rapidly proliferating cells I must not enter. This process of genuine suppuration of the blood-clot removed all the difficulties I had felt in interpreting the post mortem appearances in pyaemia, and also its clinical features.

Having become familiar with the appearances of these cells in suppurating coagula, I was able to recognise them in acute abscesses in the human subject, and to demonstrate them to others by mixing carmine with the pus, so as to render clearly defined the limits of the pellucid bodies of the cells, which otherwise would have been regarded as liquor puris.

I am, of course, aware of the great importance of the emigration of leucocytes, discovered by Cohnheim, and rendered immeasurably more interesting by Metchnikoff's observation of their phagocytic powers; and I know that collections of pus have often such an origin. But I am quite satisfied that this is not the exclusive mode of pus-formation, and that it is often produced by the proliferation of cells, as was first taught by my illustrious predecessor in this chair of two years ago (Professor Virchow), in the *Cellular Pathologie.*

While these investigations into the nature of pyaemia were proceeding, I was doing my utmost against that deadly scourge. Professor Polli, of Milan, having recommended the internal administration of sulphite of potash on account of its anti-putrescent properties, I gave that drug a very full trial as a prophylactic. I have notes of a case in 1864, in which, after amputating the thigh for disease of the knee-joint, I gave ten grains of the sulphite every two hours from the time of the amputation; and when, on the sixth day, an ominous rigor occurred, I doubled the frequency of the administration. Death, however, took place nevertheless, and this was by no means my only experience of such disappointment.

At the same time, I did my best by local measures to diminish the risk of communicating contagion from one wound to another. I freely used antiseptic washes, and I had on the tables of my wards piles of clean towels to be used for drying my hands and those of my assistants after washing them, as I insisted should invariably be done in passing from one dressing to another. But all my efforts proved abortive, as I could hardly wonder when I believed, with chemists generally, that putrefaction was caused by the oxygen of the air.

It will thus be seen that I was prepared to welcome Pasteur's demonstration that putrefaction, like other true fermentations, is caused by microbes growing in the putrescible substance. Thus was presented a new problem: not to exclude oxygen from wounds, which was impossible, but to protect them from the living causes of decomposition by means which should disturb the tissues as little as is consistent with the attainment of the essential object.

It has been since shown that putrefaction, though a most serious cause of mischief in wounds, is not its only cause. In other words, it has been proved that there are microbes which produce septic effects without occasioning unpleasant smell. But the principle that first guided me, still retains, I believe, its full value, and the endeavour to apply that principle so as to ensure the greatest safety with the least attendant disadvantage has been my chief life-work.

OBITUARY NOTICE OF THE LATE JOSEPH JACKSON LISTER, F.R.S., Z.S.

WITH SPECIAL REFERENCE TO HIS LABOURS IN THE IMPROVEMENT OF THE ACHROMATIC MICROSCOPE

Contributed in a Letter to the President of the Royal Microscopical Society.

[*Monthly Microscopical Journal*, March 1, 1870.]

Communicated by the President at the Anniversary, February 9, 1870.

Edinburgh, *February* 8, 1870.

MY DEAR SIR.—In compliance with your request, I proceed to furnish you with some particulars regarding my late dear and honoured father.

He was born in London on the 11th of January, 1786, his parents being highly respected members of the Society of Friends. At fourteen years of age he left school to assist his father in the wine trade: but though he was for many years closely occupied in business, he contrived, by early rising and otherwise, to supplement largely the plain, though good, school education he had received, and he was in many respects a self-taught man. Such was the case as regards his mathematical knowledge, which he turned to such excellent account in his labours for the improvement of the microscope.

His predilection for optics manifested itself very early. He used to tell how, when a little child, he enjoyed looking at the prospect through air-bubbles in the window-pane, which improved the vision of the then myopic eye and enabled him to see distant objects with distinctness. This fact afterwards led him to think it probable that in very young children the eye is generally myopic. The same taste was indicated when he was a boy at school by the circumstance that he alone of all the boys possessed a telescope.

The achromatic microscope was early an object of interest to him; but it was not till the year 1824, when he was thirty-eight years old, that he did anything to improve the object-glass. His first work of this kind is recorded in a note, dated 1825, to the following effect: 'The $\frac{4}{10}$ and $\frac{2}{10}$ achromatic object-glasses, made by W. Tulley at Dr. Goring's suggestion, delighted me by their beautiful performance, but they appeared to me to have a great disadvantage in consequence of the thickness in proportion to their focal length, which W. T.

thought could not be avoided. I therefore induced him to make for me one of $\frac{9}{10}$ much thinner in proportion, and had the satisfaction to find its performance *very nearly* equal to his best $\frac{2}{10}$. In one respect, indeed, it is superior; showing when in good adjustment the reflection from a minute ball of mercury a bright point in any part of the field, while in the $\frac{2}{10}$ and $\frac{4}{10}$ it is so shown only in a small portion of the field near the centre, and in the rest has a bur shooting outwards.' This bur, of which a sketch is given, is the first mention of the 'coma' which afterwards formed so important a subject of his investigations. The note goes on to describe a suggestion for another combination, illustrated by drawings of magnified views of the curves of the glasses, executed with his usual extreme neatness and accuracy; and it concludes with the words, 'tried many experiments to ascertain the best means of correcting small errors in aberration.'

The note from which these quotations are made is the first of a long series of accounts of experiments, with remarks upon them, indicating an amount of labour of which, as I never saw the papers before, and as the work was for the most part done either before my birth or during my early childhood, I had previously had no idea. The notes are beautifully arranged, and might well be published just as he left them. I must, however, content myself with mentioning, in chronological order, some of the most interesting of their contents.

In 1826, after a description of Amici's reflecting microscope and an account of its performance, I find further projections of object-glasses for Mr. Tulley, followed by a drawing for the engraver to illustrate a description of Tulley's microscope, published by that optician. A copy of this pamphlet has been preserved, and the first page begins with this acknowledgement: 'Before commencing the description of the microscope it will be proper to state that the construction of the instrument and its apparatus was suggested and made from original drawings by my friend, J. J. Lister, Esq., whose ingenuity and skill in these matters are very generally acknowledged.' The chief novelties in this instrument, besides the improved object-glasses, were the following:—

Graduated lengthening tube to the body. The stage-fitting for clamping and rotating the object. A subsidiary stage. A dark well. A large disc, which would incline and rotate for opaque objects. A ground-glass moderator. A glass trough. A live-box made with flat plate. A combination of lenses to act as condenser under the object (apparently the first approach to the present achromatic condenser). The erecting-glass; and the adaptation of Wollaston's camera lucida to the eye-piece.

The value of the erecting-glass for facilitating dissections under low powers is, perhaps, even yet not sufficiently appreciated.

The camera lucida had long been a favourite instrument with my father

for drawing landscapes; and I may add that the tripod which he invented for supporting the drawing and the camera is that which is now universally used by photographers.

In December of the same year occurs an account of an examination of a set of four plano-convex lenses, each consisting of a bi-convex of plate glass and a plano-concave of flint glass cemented to it by varnish, constructed by Chevalier, of Paris. Various interesting observations are here met with. He found that the maker had done injustice to his own instrument by shutting out a needlessly large portion of circumferential rays; and that when the apertures had been enlarged by increasing the holes in the stops, the glasses performed much better, so as to 'give him strong doubts of the figure of these small achromatics being injured by varnish' (for in Tulley's glasses the constituents of the compound lenses were not cemented together), and he remarks on the great advantage that would be derived from cementing, if unobjectionable otherwise, in facilitating the manufacture.

He made various trials with these glasses in combination, and remarks: 'I will put down my trials of the glasses as they were made. Some of them have surprised me; and they will show, I think, remarkably, the advantage to science and art of collating the detached labours on the same subject, of distant individuals. The French optician knows nothing of the value of aperture, but he has shown us that fine performance is not confined to *triple* object-glasses' (Tulley's were triples); 'and in successfully combining *two* achromatics he has given an important hint, probably without being himself acquainted with its worth, that I hope will lead to the acquisition of a *penetrating power* greater than could ever be reached with one alone.' In the light of subsequent events this reads almost like a prophecy.

With respect to a combination of one of Chevalier's glasses with one of Tulley's, he writes: 'The performance of this compound is the finest I have ever seen produced by achromatic glasses, and furnishes, I think, a very important fact. Its virtual focus is ·52 inch, while W. Tulley's $\frac{3}{10}$ is but ·33 inch, and Chevalier's combination only ·26 inch; yet it goes beyond them both in clear positive power of defining.'

But the most interesting parts of this note are those which record, for the first time, some puzzling appearances in combinations of compound lenses, which ultimately led him to his great discovery of the two aplanatic foci. Each of Chevalier's compound plano-convex lenses when used singly presented a bur or coma outwards, but when two of them were combined, this coma, instead of being exaggerated, as might have been expected, was '*less than with any single glass*', while the performance in other respects was satisfactory. 'Observing

the advantages resulting from this combination,' he 'tried some others', among the rest two of Tulley's triple glasses, each of which taken singly was of fine performance. But, instead of unmixed improvement resulting, we find it noted: '*N.B.*—Each glass *separately* shows a bright object all over the field without bur, and is *not far from being achromatic.* But, *combined,* the objects not in the centre have a strong bur INWARDS, the colour is much under-corrected, and the spherical aberration is not right.'

In the following year we find similar anomalous appearances recorded. Thus, on one occasion, on using in combination a triple glass of Tulley's free from coma and otherwise excellent, and a double plano-convex in which, when used alone, the spherical aberration was rather under-corrected and an outward coma presented itself, the combination proved to have the spherical aberration rather over-corrected and showed an inward coma. Again, a bi-convex glass of Herschel's construction, consisting of a bi-convex of plate with a flint meniscus, when used alone with the flint surface foremost had little or no coma, but when combined with a triple $\frac{9}{10}$ free from coma, showed a 'bur much inwards'. The same glass used alone with the plate side foremost showed a 'bur inwards', but when it was combined with the triple, which had before had the effect of inducing an inward coma, the bur inwards was changed to a 'bur slightly outwards'.

Such are samples of the perplexing and seemingly inconsistent observations recorded at this period. To a less accurate observer and a less acute mind they must have proved utterly bewildering. But he did not despair of finding an explanation of the appearances, and the last note on the subject in that year alludes to the angle formed by the rays of light with the concave lens as affecting the direction of the coma.

He was afterwards occupied for a while with planning triple glasses to be used in front of the previous triples of Tulley, and with general arrangements for the instrument. But, in November 1829, a set of five plano-convex glasses manufactured by Utzschneider and Fraünhofer, very similar to those of Chevalier but uncemented, having been placed freely at his disposal by Mr. Robert Brown, the botanist, he set to work in good earnest to strive to solve the difficult problem. The experiments made with this object are recorded in a series of tables, the first of which gives an accurate description of each of the five new glasses and also of those of Chevalier, and of their performance when used singly. The others give the effects of various combinations of those glasses upon the chromatic and spherical aberrations and upon coma. He had previously observed, as mentioned in a note in 1827, that in a particular combination of two glasses the coma was diminished by separating the glasses. And we find in these

tables that the performance of each combination is given, both when the glasses are close and when they are separated a certain distance from each other. As we look down the tables we seem for a while to find confusion worse confounded. We see, indeed, abundant evidence of the great effect produced both upon coma and upon spherical aberration by the distance between the glasses ; but the effects appear altogether inconsistent, if not contradictory. Thus, as regards coma, two of Fraünhofer's glasses which, if used singly, gave slight outward coma, gave when combined and near together a great deal of coma rather outward, but when separated by 1·2 inches an almost entire absence of coma, and what there was rather inwards. But, farther down, three glasses which each gave outward coma when single, are seen to present in combination an inward coma when close, and an outward coma when separated. With respect to spherical aberration we seem for a while to meet with something like a law. We find that two glasses which, if used alone, are free from spherical error, when combined and close have that error over-corrected, but this over-correction is removed by separating the glasses. And the same thing occurs with several other combinations. But looking down the table we come to a case where the excess of spherical correction caused by a combination of three glasses placed close, cannot be removed by separating them, and then follows a combination of three, in which 'the excess of spherical correction is *increased* by separating for the short distance we can go'. And, again, a little lower occurs a combination, also of three, in which 'the excess of spherical correction is diminished but not conquered' by separation of the glasses.

Yet out of this apparent confusion he educed a principle which reconciled all the conflicting appearances, and formed the basis upon which all fine combinations for high powers of the microscope have rested. He found that in a plano-convex lens, constructed like those above described, in which a double convex of plate has its colour corrected for a moderate aperture by a plano-concave of flint, the effect of the flint lens upon the spherical error caused by the plate varies remarkably according to the distance of the luminous point from the glass. If the radiant is at a considerable distance, the rays proceeding from it have their spherical error under-corrected ; but as the source of light is brought nearer to the glass, the flint lens produces greater proportionate effect, and the under-correction diminishes till at length a point is reached where it disappears entirely, the rays being all brought to one point at the conjugate focus of the lens. This, then, is an aplanatic focus. If the luminous point is brought still nearer to the glass, the influence of the flint lens continues for a while to increase, and the opposite condition, of over-correction, shows itself ; but on still further approximation of the radiant, in consequence apparently

of a reversal of the relations to each other of the angles at which the rays of light meet the different curves of the lens, the flint glass comes to operate with less effect, the excess of correction diminishes, and at a point somewhat nearer to the glass vanishes, and a second aplanatic focus appears, and from this point onwards under-correction takes the place of over-correction, and increases till the object touches the surface of the glass. Such a lens, then, has two aplanatic foci: for all points between these foci it is over-corrected, but under-corrected for points either nearer than the shorter or more distant than the longer focus. A knowledge of these facts enables the optician to combine a pair of such lenses with perfect security against spherical error. In order to do this, to quote from my father's paper in the *Philosophical Transactions*, read on the 21st of January, 1830, 'the rays have only to be received by the front glass from its shorter aplanatic focus, and transmitted in the direction of the longer correct pencil of the other glass.' The light then proceeding through each glass, as if from one of its aplanatic foci, is brought correctly to a focus by the combination. Supposing two glasses to have been so arranged, if the front glass is carried nearer to the back one, light proceeding from the shorter aplanatic focus of the front glass will reach the back glass as if from a point nearer than its longer aplanatic focus, that is to say, from a point between the foci, and therefore the spherical error will be over-corrected. On the other hand, separation of the glasses beyond their original interval produces under-correction. Thus, by merely varying the distance between two such lenses, the correction of the spherical error may be either increased or diminished at pleasure according to a definite rule, and slight defects in the glasses can be remedied by simply altering their relative position, the achromatism of the combination being meanwhile happily little affected.

Another beautiful circumstance connected with the aplanatic foci is that of their relation to the coma. At the shorter focus the coma is inwards, at the longer focus outwards; and in a combination of two lenses arranged as above described, the inward coma from the shorter focus of the front glass destroys the outward coma from the longer focus of the back glass, and 'the whole field is rendered beautifully flat and distinct'.

The same principle applies when the lenses are of different form, and when more than two are combined. Thus the manufacture of the achromatic object-glass was reduced from a matter of uncertainty and empiricism to a scientific system, and has become susceptible of a degree of perfection that would otherwise have been impossible.

But though he had thus discovered the principle of construction, his own abours were far from being concluded. The next section of his notes is labelled

'Memoranda on object-glasses made for experiment, December 1829 to May 1830'. These include a great number of interesting observations, such as trials of lenses of different forms; descriptions of the 'colours of over, under, and right correction', as seen when the object is out of focus, illustrated by coloured sketches; experiments on the effects of varnish; proof that a compound lens has more effect on spherical and chromatic aberration when placed behind in a combination than when in front, &c.

Then follow a set of notes of peculiar interest, describing the effects of glasses made by his own hands. These are referred to in a letter to Sir John Herschel, of which he preserved a copy, together with Sir John Herschel's reply. The letter is dated London, 24th of 2nd month (February), 1831. In it the following passages occur: 'Finding, however, that W. Tulley was too busy to pursue for me the experiments I wished for ascertaining how compound object-glasses could be combined to the greatest advantage, I determined in November last to make a trial myself. The result was, I acknowledge, beyond my expectations; for without having ever before cut brass or ground more than a single surface of a piece of glass, I managed to make the tools and to manufacture a combination of three double object-glasses, without spoiling a lens or altering a curve, which fulfilled all the conditions I had proposed for a pencil of thirty-six degrees. . . . Long illness among my children afterwards absorbed all my leisure till about three weeks ago, when I made a second and more complicated trial, projected for obtaining the same effect with a much larger pencil. This is just finished, but not without altering one of the original curves; and its plan might be improved if I could spare time to make another set. Still, I flatter myself these attempts would interest thee, as showing how easily the principle I mastered may enable an utter novice in glass-working to produce vision which I have not yet seen exceeded.' In the second of these trials he deviated from the plano-convex form of the lenses, employing a combination of three, of which the front was a double meniscus, the middle a triple, and the back one a double plano-convex. The reasons for preferring these forms are given in full detail in his notes, among which occurs the ingenious idea of regarding the triple with the middle of flint glass as divided by an imaginary line through the flint into two double achromatic glasses, each of which may be considered separately as having two aplanatic foci. The object he proposed to himself was 'a construction fitted to obtain the largest pencil with good front space and without coma'; and after describing the mode by which this was arrived at, he says, 'This combination proves most satisfactorily the advantage of keeping the angles of the rays at all the different curves moderate, the vision being singularly definite and easy. . . . Indeed, taking all

together, I think I have met with nothing to equal it—the distance of the front glass from the object being 0·11 full.'

Having now completely satisfied himself of the applicability of his principle, he devoted much of his leisure for several years to various investigations by aid of the instrument which he had so greatly improved. Some of the results are well known to the public. Selections from his observations on zoophytes and ascidians, beautifully illustrated by sketches from life by the camera lucida, form a classical paper in the *Philosophical Transactions*. But a laborious inquiry, chiefly conducted by means of the microscope, into the limits of human vision, as determined by the nature of light and of the eye, has never been published. He had at one time almost prepared an account of it for the press, when the illness of his eldest son, which ended fatally, threw such a cloud over his spirits that for several years he had not the heart to complete the work. And when at last he did resume it, and was on the eve of publication, he learned that the Astronomer Royal, Professor Airy, had reached the same conclusions, though by a different road, and so abandoned the idea, a circumstance in my opinion deeply to be regretted.

But to return from this digression. The next note in order of date regarding the construction of the microscope is one made in 1837, headed 'Remarks on A. Ross's suggestion for three glasses to admit a large pencil, which J. J. L. thought would not answer. A. R. tried it, and found it a failure, before trying J. J. L.'s suggestion below.' Then follows a drawing of a proposed combination of three glasses 'for the same object', giving the dimensions of the lenses and the curves of the various surfaces, with a statement of the effect proposed to be produced by each glass upon spherical aberration and coma. This resulted in Ross's celebrated $\frac{1}{8}$-inch object-glass, the construction of which was afterwards adopted by the other principal London makers.

A statement in his handwriting found among his papers gives, in a few words, his relations to the British microscope :—

'I had been from early life fond of the compound microscope, but had not thought of improving its object-glass till about the year 1824, when I saw at W. Tulley's an achromatic combination made by him at Dr. Goring's suggestion, of two convex lenses of plate glass, with a concave of flint glass between them, on the plan of the telescopic objective. They were very thick and clumsy. I showed him this by a tracing with a camera lucida, which I had attached to my microscope, and the suggestions resulted in "Tulley's $\frac{9}{10}$", which became *the* microscopic object-glass of the time. But the subject continued to engage my thoughts, and resulted in the paper *On the Improvement of Compound Microscopes*, read before the Royal Society, on the 21st of January, 1830, announcing

the discovery of the existence of two aplanatic foci in a double achromatic object-glass. This has formed a basis for subsequent important improvements, the object of which has always been to obtain sharpness and achromatism over the field in the picture from a larger and larger pencil; this being an essential to obtaining higher and higher defining power.

'After succeeding fairly in a trial combination with this view, I left the subject for a while, hoping it would be pursued by opticians. But the glasses produced by the makers continued to be on the first simple construction of two or three plano-convex compound lenses till the beginning of 1837. At that time I called on Andrew Ross regarding some object-glasses he had made to a microscope for Richard Owen; when he told me he had been long engaged in unsuccessful trials for a new construction. And at his request I gave him a projection for a $\frac{1}{8}$-inch objective of three compound lenses, the front one a triple, which he soon worked out successfully, and it became the standard for high power for many years.

'For lower powers I suggested at the same time a double combination, and, borrowing of him a lens from among his former failures, and applying it in front of one of my own at home, obtained at once the performance required.

'It was natural that A. Ross should regard these as trade secrets; and accordingly, in his article on the microscope in the *Penny Cyclopaedia* he does not mention them, giving only the earlier construction of my article in the *Transactions*. The same is given afterwards in the treatise which J. Quekett asked at the point of its publication to dedicate to me! And I did not feel required to disclose A. Ross's secrets. After a while, with his consent, I instructed James Smith, 1840, to execute the same construction for inch and half-inch glasses. Even in 1843 it was with the understanding that he should not go to deeper powers than $\frac{1}{4}$-inch, and "Smith's quarters" were long in repute. In these projections the endeavour was to keep the angle of pencil at each surface of the glasses as moderate as was consistent with the other essentials; and by degrees the pencil admitted has been enlarged beyond my expectations. Some variations too have been since made in the construction in which I have had no part; but for all, the principle of the two aplanatic foci has furnished the clue.'

I believe I am correct when I state that in foreign microscopes also, object-glasses of high powers and fine performance are constructed on the same principle. And thus it seems not too much to say, as has been lately said by a Professor in one of our Universities—the son of one who was formerly associated with my father through a common love of science—that he was 'the pillar and source of all the microscopy of the age'.

Although in this notice I have confined myself chiefly to matters connected with the microscope, it is right that I should add that these were far from forming the exclusive occupation of his leisure hours. The comprehensive grasp of his intellect and the extent and variety of his attainments were as remarkable as the accuracy and originality which characterized his microscopical work. Indeed there were few subjects in literature, science, or art with which he did not show himself more or less familiar. His clear, calm judgement and strict integrity made his opinion highly valued among his friends in matters of difficulty or dispute. He was most unselfish, and scrupulously tender of hurting the feelings of others, and extremely generous in the pecuniary support of public philanthropic objects, as well as in secret acts of charity. Though warmly attached to the religious Society of Friends, to which he belonged, he was a man of very liberal views and catholic sympathies. But the crowning grace of this beautiful character, though it might veil his rich gifts from those not intimate with him, was a most rare modesty and Christian humility.

Living to an advanced age, he retained his activity of body and mind to the last. But while to his friends this appeared remarkably the case, he was himself keenly alive to the gradual effects of years upon him, and his sensitive nature shrank from the idea of the helpless state to which he might be brought if his life should be prolonged like his father's, who lived to ninety-eight; and he often expressed his desire that he 'might not outlive his powers'. His wish was granted. He had only just returned from a stay at the sea-side, where he had enjoyed long rambles and excursions, when a feverish attack rapidly but almost painlessly prostrated his strength. Fully aware that his end was approaching, his loving interest in others was conspicuous to the last, while for himself he showed no anxiety, except the earnest desire for a speedy dismissal. He died at Upton House, in Essex, on the 24th of October, 1869, in the eighty-fourth year of his age.

Believe me,

My dear Sir,

Yours very sincerely,

JOSEPH LISTER.

To the Rev. J. B. Reade, F.R.S., P.R.M.S.

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